UNITED STATES DEPARTMENT OF AGRICULTURE

REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1928

PREPARED BY THE

OFFICE OF EXPERIMENT STATIONS

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Washington, D. C. October, 1929

REPORT ON THE AGRICULTURAL EXPERIMENT STATIONS, 1928

By E. W. ALLEN, W. H. BEAL, and H. M. STEECE[1]

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INTRODUCTION

This report relates to the progress of the system of agricultural experiment stations in the United States and some of the problems of their organization and administration.

While this system was established mainly as a result of Federal legislation, in 1887, the relation of the Federal Government to it is one of participation rather than of control. It has continued its aid through increasing appropriations, and that these might be safeguarded and used to best effect the country over it has provided for a general supervision. To secure the advantages of study of the enterprise from a national viewpoint and such aid as might be afforded in developing broad policies and standards, it has maintained in the Department of Agriculture a central office which serves, among other things, to give a measure of coherence to the enterprise and to record its progress.

[1] With the collaboration of other members of the office staff.

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THE NATIONAL SYSTEM

Experiment stations in all the 48 States shared in the Federal funds during the year. As is generally known, these are connected with the agricultural colleges established under the land-grant act of 1862, except in the case of Georgia, where the station is independent of the college. In addition two State stations (in Connecticut and New York), located away from the college stations but under the same management, received a share of the Federal appropriations.

Besides these institutions in the States, experiment stations are maintained under grants from the Federal Government in Alaska, Hawaii, Porto Rico, Virgin Islands, and Guam, the direction of which is assigned to the Office of Experiment Stations. These form a part of the general system, which gradually has been extended from the States and Territories to all the important insular possessions.

In addition to the stations receiving Federal aid, six separate stations were maintained in the States, with local support. To a considerable extent these related their work to that of the other stations so that their activities contributed to the output of the whole.

To further facilitate the work of the stations in meeting the needs of their localities, there were 114 substations of a permanent nature connected with the State stations, designed to serve the problems of special localities or particular branches of the agricultural industry, such as cranberry growing, the blueberry industry, tobacco growing, the cattle industry under range conditions, and the like. The work out in the States was further supplemented by 59 experimental farms and 255 experimental fields, employed to carry on experiments in local adaptation of crops and practices, determine the fertilizer needs of different types of soils, etc.

MAGNITUDE OF THE ENTERPRISE

It will be evident from the above that agricultural experimentation and research as represented by the experiment stations has reached enormous proportions. Not only is the system the most extensive and far-reaching one ever built up for agricultural inquiry; it is the largest organized effort for research in any branch of science or industry. And it is still a growing enterprise.

The development to the present magnitude is a reflection of the great confidence in the power of research, especially when it is organized and is directed to the vital problems of the industry in their local and national aspects. The broad and extremely varied nature of these problems as presented by the wide extent of the country, and the fundamental relations of these problems to the ability of the industry to cope with and adjust itself to changed conditions, are an irresistible challenge to administrative officers and workers alike. And the confidence so abundantly evidenced by Federal and State appropriations and by the provision of modern buildings and other needed facilities, presents a responsibility for the effective organization and administration of this great enterprise which no one in authority can fail to realize.

While there are innumerable evidences of the gratifying character of the progress made—and the outlook never was more encouraging—the opportunity for growth and improvement needs to be frankly recognized and provided for. This is the more important because the financial support is still growing and the nature of the expectations and the demands are bound to become more exacting.

A YEAR OF PROGRESS

Judged from every angle, the year was an unusually prosperous one and was marked by notable growth. The financial support was the largest ever reported, reaching the imposing figure of $15,000,000. The personnel increased by fully 200 persons on the regular forces of the stations, bringing the number up to over 3,000. There were many additions to the list of projects. In many cases the lists were cleared up, projects that had become inactive were eliminated, and special attention was directed to those approaching completion. And despite the tendency to publish the more technical aspects of the investigations in scientific journals, the amount of matter issued in the regular station series was well maintained.

The physical plant was enlarged by buildings shared by the stations aggregating in cost $800 000; and these, together with other permanent equipment and facilities, brought the total increase for the year up to over a million and a half dollars, an unusually large growth in material facilities.

Noteworthy advances were made in strengthening the research in various

lines, in bringing thoroughly prepared persons into the staffs, and in providing more adequately for matters of administration. While there is still opportunity for improvement in the latter respect, the trend is significant and encouraging for the most part.

Progress also was made in perfecting the organization and personnel in the newer lines of agricultural economics, home economics, and rural sociology. The inauguration of research in these subjects has given considerable difficulty in some of the States because ideas regarding them had not been so well matured, directors frequently felt at a disadvantage, and the number of persons available with suitable training and mature outlook was rather limited. These difficulties, however, are gradually correcting themselves, especially where thoughtful consideration is given and the effort is made to maintain standards commensurate with the requirement of effective inquiry.

SOURCES OF MAINTENANCE

The experiment stations are State institutions, not Federal. They constitute a fine example of cooperation between the Nation and the States in the maintenance of research. Their support comes from both sources.

During the fiscal year 1928, each State received Federal appropriations amounting to $15,000 under the Hatch Act, $15,000 under the Adams Act, and $40,000 under the Purnell Act, a total of $70,000. The revenue under the Purnell Act increased by $10,000, or a total of $480,000 for all the States. The aggregate contribution from the Federal Government was therefore $3 360,000, to which is to be added $237,640 for the stations in the outlying territories and insular possessions.

The contributions from sources within the States, including appropriations and allotments, sales, fees, etc., amounted to $11,442,773, or more than $3 for every $1 from Federal sources. This shows the liberal manner in which the States are bearing their part in the support of these institutions, and indicates that despite the initiative supplied by the Federal Government for the establishment of the stat ons in many of the States, the responsibilities for them as State institutions are fully recognized and maintained.

No sharp separation or distinction can be made between the organization and work under the Federal appropriations and those of the States. They are used jointly. In many cases projects receive their support from the two sources. While on occasion more latitude may be exercised in the use of State funds, especially in adapting the work to local needs, in general the objects and standards are alike, and the output of thoroughgoing investigation supported by State funds supplements in a very large way that from the Federal appropriations.

THE CONTRAST OF 40 YEARS

The year marked the fortieth anniversary of the agricultural experiment stations as a country-wide system receiving Federal aid. The establishment of this system dates from the passage of the Hatch Act on March 2, 1887.

The first appropriation under that act was in 1888. In that year experiment stations in all the States (then 38 in number), and the Territory of Dakota received the national funds, amounting to $15,000 each, or a total of $585,000. At that time there were two stations each in Alabama, Connecticut, Massachusetts, New Jersey, and New York, and three in Louisiana. About $125,000 was derived from State appropriations, fees, sales of farm products, etc. The total amount available to the stations in 1888 was therefore about $710,000. Their forces numbered about 400 persons.

These resources at the inception of the national system compare with over $15,000,000 in 1928, and a force of 3,000 persons. The revenues have increased, therefore, to more than twenty times and the working force to more than seven and a half times those in 1888. The growth in available man power has been far greater than these numbers indicate, owing to the larger percentage of time free from teaching or other duties. Formerly the station work was in large part secondary or incidental to other college activities; now it has become to large extent a primary one for leading workers.

In their early history the stations were called upon to do a relatively large amount of regulatory and service work, not permitted under the Federal funds but supported by State appropriations. To an increasing extent such work now is being taken care of by other agencies and the stations are thus left freer to devote their resources and energies more strictly to research. At that stage also a large share of the work was done by the

simpler observational and experimental methods, in field, orchard, and feeding stall; now the more exact and quantitative methods of laboratory, plant house, respiration chamber, and other refinements are being relied on to a far greater extent, with many improvements in technic and method.

The development of fundamental research with an ultimate practical aim is the present ideal of experiment station work. As one station director (W. C. Coffey) recently said:

> The agricultural experiment station was founded for the purpose of solving problems arising out of the farmers' occupation and life. It is expected that those in charge shall be practical minded, at least to the extent of basing its program primarily on situations and conditions arising in agriculture or in fields closely related thereto. Almost of necessity, broad observational and descriptive methods of experimentation must be used in the first attack on a newly found field problem. But out of the larger, cruder field problems other problems requiring a different type of attack arise. . . . The modern tendency of experiment stations is to follow problems through until conclusions can be based on intelligent and carefully prosecuted scientific procedure.

This development is reflected in the many buildings specially designed for advanced investigation in most of the States, which are being added to, every year, and even more strikingly in the extent of specialization and of rigorous preparation on the part of the workers.

This growing intensity and specialization, with laboratory and controlled facilities so largely taking the place of natural farm conditions, has not made the experiment stations or their experts any the less practical. On the contrary, it has made them more efficient and reliable, and able to reach further into an understanding of the factors and the reasons involved in complex questions—to follow much further the connection between causes and effects.

The search for fundamental knowledge frequently leads into the field of pure science, but by this means a surer foundation is laid for the solution of practical questions. It is only by such means that the "what," "how," and "why" of many basic problems can be determined, and until this is done no problem can be considered intelligently solved. In the realization of this and with increasing financial support stimulated by public confidence and demand, the stations are enlarging their fundamental studies along with the scope and variety of their activities, and with these things comes a clearer conception of what is involved in the effective organization and execution of research.

THE PROJECT RECORD

The scope and character of the work of the experiment stations is reliably indicated by the research projects in which they are engaged. The classified list of projects prepared during the past year includes more than 6,600 projects grouped as follows: Agricultural chemistry 44, agricultural economics 491, agricultural engineering 268, animal husbandry 973, bacteriology and similar studies 12, botany 26, dairying 121, economic entomology 507, economic zoology 40, field crops 1,758, food technology 17, forestry 122, genetics 181, home economics 124, horticulture 1,197, meteorology 10, plant pathology 565, plant physiology 69, rural education 14, rural sociology 60, soils and fertilizers 538, and veterinary medicine 217.

During the year 1927–28, under the Federal funds, there were in active operation 438 research projects supported entirely or in part from the Adams funds, and 895 similarly supported from the Purnell fund. Differences in methods of administration and in available funds at the several stations result in considerable variations in the number of projects set up for Adams and Purnell fund support. For instance, some of the stations allot their funds purely on the project basis, while others devote the Purnell and Adams funds to the support of a particular department, or departments; and still others use these funds entirely for salaries, supplying the money needed for necessary maintenance expenses from other sources. One station, for example, had but 6 Purnell projects and another 8, whereas several other stations had from 25 to 31 projects which were receiving support from that fund.

These variations from the average of about 18 Purnell projects per State occurred, notwithstanding the fact that each State received the same amount of money from this fund, namely, $40,000. It was due to differences in the method of handling the fund, and in a large part to the availability of supplemental funds from other sources. Usually there were more accepted projects than could be supported entirely from the Purnell appropriation.

During the year 103 new or restated Adams and 280 new or restated Purnell projects were approved. Of these

63 under the Adams fund and 40 under the Purnell fund were regarded as restatements. The outlines on which some of the Adams projects have been operating were submitted many years ago, and as a result of the findings within the projects themselves and of advances of others along similar lines, the original outlines were no longer adequate to indicate the scope and procedure. Many of the approved Adams projects, therefore, were restatements of former projects, as was also the case with a few of the proposals under the Purnell fund.

Several of the States restated a large proportion of their Adams program, as well as several Purnell projects. To some extent this action was voluntary on the stations' part because of recognition that the outline was no longer adequate for the current work, while in other cases restatements came in response to requests from the office because the annual visits or correspondence showed that the course of the investigations had changed or the lines of attack were modified sufficiently to necessitate restating. The restatements were generally distinct improvements over the earlier project outlines. This was true especially in presenting a more limited objective, with effort concentrated more definitely on phases whose significance had been developed as a necessary step in the solution of a broader problem.

The distribution of the Federal funds among the different fields of inquiry by no means conformed to the proportionate number of all the station projects in different subjects. As has been pointed out in previous reports, a considerable proportion of the Purnell fund was assigned to studies in agricultural economics, home economics, and rural sociology. About 40 per cent of the Purnell projects were in these three fields. Among these subjects agricultural economics rereceived about $550,000; home economics, $205,000; and rural sociology, $68,000. Less than 10 per cent of the Purnell projects were in field crops and nearly 8 per cent were in horticulture, to which approximately $140,000 and $120,000, respectively, were allotted. About $120,000 was devoted to studies in soils and fertilizers, and $80,000 to plant diseases, subjects closely related to field crops and horticulture. Approximately $290,000 was expended in the field of animal husbandry and dairying, which included 17 per cent of all the Purnell projects set up. Roughly, about $88,000 was devoted to entomology and economic zoology projects, and $40,000 to $50,000 was used in each of the fields of animal diseases, agricultural engineering, and genetics.

The Adams fund has been more closely restricted to use in the solution of fundamental problems and investigations of more permanent value and more general application. Approximately $125,000 of this fund was expended on projects in soils and fertilizers, $105,000 on projects in plant diseases, and $90,000 on genetic studies with plants and animals. Animal-husbandry problems, mainly in nutrition, received $80,000; animal diseases, $70,000; and $55,000 was applied to entomology and economic zoology studies. There were 94 Adams projects on plant diseases, 62 on soils and fertilizers, 59 on genetics, and 49 on entomology and economic zoology.

New projects were distributed over practically all subjects, but there was a pronounced tendency for several States or groups of States to work on similar problems. Aside from the national cooperative projects there is much regional cooperation. Several of the northwestern States with one of the Canadian Provinces have a definite organization for the study of oil sprays, in which individual States take a special phase of the problem and give it concentrated study. Practically all of the fruit-growing States have been much interested in investigations to determine means of removing excess spray residue from fruits. The development of new high-nitrogen-content fertilizers has given impetus to the study of sources of nitrogen and the nitrogen requirements of special crops, in carefully laid-out laboratory and field experiments in which variables are largly under control.

While many new agricultural economics and home-economics projects appear to be based on the study of practices and opinions, there is a tendency to go beyond the experience of others and to develop new methods of investigation more comparable to the methods employed in other subjects. The basic data are obtained by a trained investigator who does more than serve merely as a recorder of data and opinions of farmers and farmers' wives. Definite standards and methods are being worked out for home-economics projects dealing with the study of the influence of wear, laundering, and sunlight on the durability of fabrics. The

methods and technic for home-equipment studies show considerable improvement from a research standpoint through consultation and cooperation with agricultural engineers, physicists, and other specialists. Farm management and marketing studies are being interpreted with reference to their relation to national conditions, and the objectives are fundamentally concerned with the basic cause of relationship of the results obtained.

The number of projects of an empirical nature in animal husbandry and field crops is becoming progressively less. More emphasis in these fields is placed on nutrition, genetics, conditions of growth or production, and disease investigations. Preliminary studies or knowledge already in hand on the applied subject point out the important problem, and it is solved with the aid of one of the more specialized sciences. The cut-and-try method of experimentation is thus being replaced by a more carefully thought-out plan of attack designed to discover basic facts and the range of their application.

Outstanding new lines of work include such inquiries as the genetic and physiological effects of X-ray irradiation of plants, the relation of cytoplasmic structures to heredity, fundamental studies of the nutritional requirements of animals and man at different ages and under different conditions, determination of nutritional requirements of plants under controlled conditions, fundamental phases of nitrification and denitrification in the soils, and nitrogen losses from the soil due to run-off water and drainage.

Several of the experiment stations have given increased attention to the development of well-balanced and interrelated working programs. For instance, one station has centered its Purnell work quite largely around the canning industry, setting up projects in soils, fertilizers, plant diseases, genetics, entomology, horticulture, plant physiology, and agricultural economics having a direct relation to this industry. Another station has assembled facts about the agriculture and farm homes of the State in several mimeographed publications which are to serve as a record of what is known, and indicate what is needed in the way of agricultural adjustments. All phases of the experiment stations' activities are expected to fit in this program. Several of the Southern States have endeavored to organize important parts of their research programs around cotton problems, directing attention in their agricultural economics, agronomy, entomology, plant physiology, and plant pathology research toward the solution of problems related to that crop.

The administration of the Adams and Purnell funds by this office involves considerably more than the simple approval of projects submitted. Attempt is made to clarify the outlines of new projects, to bring the work up to standards commensurate with the present status of research, and to offer helpful suggestions which a broad viewpoint may make possible. New projects are thus subjected to critical examination and analysis before being accepted, to avoid question being raised after the work is under way. What this involves may be indicated by the fact that 105 of the new projects were modified quite materially as a result of the examination, and 23 others were finally withdrawn or rejected as not being appropriate to the Federal funds. Action was still pending on 86 projects presented during the period.

The aim in all cases is to avoid arbitrary action as far as possible and to accomplish the desired object by suggestion, or by citation of other investigations which may be advantageously taken account of, and to preserve local initiative. Frequently correspondence about new projects is quite extensive, sometimes extending to 4, 5, and 6 successive letters. To express the matter numerically, approximately 775 comments and suggestions were offered about projects, which were almost universally well received and apparently welcomed. In many cases rigid criticism was specifically invited.

George Haines.

INITIATING NEW PROJECTS

The work of the experiment stations under the Federal funds is on the basis of definite restricted projects; most of the other work of the stations is likewise now on a project basis. Ability to state a problem clearly, to analyze it into its significant features, and to recognize a workable part is an important attribute of the research worker. The project outline is one of the clearest evidences of a worker's motives, his vision, and his preparation to undertake an investigation. It is a sign of clear thinking, of a definite purpose, and of a determined course of action. The objective and the plan of procedure may be tentative, subject to change as a result of the findings or

of ideas which come with the progress of an investigation, but for the time being they give direction to the effort.

Proposals for new projects as they come to the office vary quite widely in quality and in the apparent care bestowed upon them. There has been marked improvement, but there still is a considerable proportion of the proposals which show inadequacies of one kind or another. These are not confined to any group of subjects or field of effort.

Some of these deficiencies may be mentioned because they indicate a condition which can not be regarded as satisfactory and which will affect the productivity of the work unless remedied. They may be classified as follows:

Blanket projects.—Broad and indefinite proposals with many objectives or a composite one. These propose to cover a field rather than state a problem or a workable unit. They are too general and indefinite to serve as a basis for research at this stage.

Projects overlooking previous work.—Projects that fail to take account of what has been done or of the general status of investigation on the subject. There is little excuse for this with the sources of information available. To take advantage of what has been done, and to add to it where addition is necessary in order to confirm or to supplement previous work, is fundamental to the making of a contribution. New projects in familiar fields ought to be entered upon with a full realization of the present status, the particular points that need to be strengthened, and the obligation to do work that will be constructive. The investigator or experimenter who is able to ingraft his work upon that of his predecessors is in position to magnify it into a correspondingly larger contribution.

This defect is not confined to agricultural research. A recent article[1] relating to research in general says:

> The precise extent to which research workers are wasting energy in repeating experiments that have already been made is difficult to estimate; but those who have given much attention to the study of the literature of their special subjects are aware that the proportion of labour which is wasted for lack of information on previous work is very high. It is indeed more than possible that half the energy expended in experimental research is dissipated in useless repetition.

[1] A Neglected Aspect of Scientific Research. Nature [London], 122 (1928), No. 3085, pp. 913–915.

This is a startling statement, and without more definite data would not be accepted as applying to the work of the experiment stations, but it is undoubtedly true that there is a considerable amount of repetition or of going over the same ground without change of viewpoint or method, which marks little actual advance. This is especially true in the more practical types of experimentation where the work is unwarranted except as a local test or demonstration. The difference between the experimenter and the demonstrator is that the one seeks to enlarge the field of knowledge and the other to make it more generally available. There is no excuse at the present day for the experimenter to engage in demonstration, and there is even less for him to make experiments to teach himself what he should have learned from the literature.

Projects with defective technic.—Projects that fail to embody provisions and precautions recognized as essential in good experimental procedure. One of the products of experimental work has been the recognition of elements of weakness and the strengthening of methods and procedure essential to fairly reliable results. One of the primary requirements of a comparative experiment, for example, is that variables be limited and conditions controlled so that the things compared will stand out in sufficient contrast to make an effective test possible. Failure to employ the best technic that has been developed and lack of provision for adequate checks and statistical treatment result neither in a good experiment nor a reliable demonstration, but may likely lead to confusion or uncertainty which it will require further experimenting to correct. Such work needs to be checked before it is started.

Projects in which procedure is inadequate.—Projects that rely on means which are insufficient to attain the objectives. This is as important an omission as the employment of defective technic and indicates that the proposal has not been carefully thought through. It is easy to imagine things it would be desirable to know, but it is more difficult to conceive of means of discovering and proving them. Here the means justify the ends, and the value of the results is measured by the adequacy and soundness of the procedure. The end can not be predicted with certainty, but means for affording necessary con-

trol and for effecting determinations or measurements on which success depends evidently can not be lacking. Critical examination will detect such omissions, which otherwise make the effort abortive.

Demonstrations and routine efforts.—Projects which propose to try out in the locality matters well established, or purely mechanical determinations made to accumulate general information without reference to any definite experiments or to disclosing any general fact. Routine work is necessary, but frequently it has no connection with research. Sometimes purely exploratory work is mistaken for the end instead of the beginning or basis for investigation. This is not confined to the survey type of project, which again frequently terminates with the summary of the reconnaissance instead of using it as a background on which to project inquiry. Even though interesting material is supplied for publication, a statement of the case rarely constitutes an answer to the problem.

Research is spoken of as an intellectual product. It is recognized as a result of intellectual activity—of doing mechanical and routine things or devising new means, not for themselves merely, but to carry forward an idea. The project outline, therefore, ought, itself, to be an intellectual product, carefully conceived as to purpose and the means of attaining it. Even though the aims and objects of a project may not be fully attained, it may be effective so far as it goes, and as a negative result it may be helpful to future efforts in that line.

THE COURSE OF RESEARCH

Closely related to these matters pertaining to the nature of the project are the course of the procedure, its purposeful character, and continuation as based on the nature of the returns.

Investigating and experimenting are more than preliminaries or "trouble shooting." They aim at something more permanent and enlightening than temporary or superficial makeshifts. They are more technical and penetrating than they formerly were, and this is why they are necessarily becoming more fundamental.

CONTINUITY IN RESEARCH

Most experiments need to be continuous and consecutive to accomplish the purposes intended. A large part of them are not final, but represent steps. The outcome is not a certainty, and it can not be predicted how material an advance the successive steps will mark. They may be missteps, for the very reason that they are experiments, but negative results may not be without value if they teach something that is profited by in succeeding trials.

The important thing is to plan experiments in the light of the best information available and with the intention of making them serve a definite purpose in ascertaining the necessary facts. The results will be valuable only in what they show. In making a contribution data are helpful for what can be made out of them. To summarize them and publish them for purposes of record will rarely constitute a contribution, for a contribution is a digested affair.

Every project seeks an end. It may not be a complete or final one, but, if successful, it marks something accomplished.

As pointed out in a recent report of the Committee on Experiment Station Organization and Policy, continuity in the effort to obtain the objectives of experiments and investigations is highly essential, but there is a distinction between continuity of aim and continuity of procedure. Persistence in the pursuit of an objective does not necessarily imply adherence to a fixed plan or set-up.

In the past the laying out of series of experiments to be continued through a considerable period of years was common practice, and much importance was attached to the continued accumulation of data in the expectation that ultimately they would shed light. This was a natural consequence of the pioneer stage. Experiments dealing with the complex and little-understood questions of the time, conducted under limited control of conditions or variables, could not in short periods give sufficient data for safe deductions. Avoidance of haste in drawing conclusions was as much emphasized as refinement of methods.

Importance has continued to be attached to set procedure in some types of work without critical regard for its effectiveness. Sometimes it is a cloak for routine and for failure to make progressive advance. Perseverance in a set course without evidence of advance or after the procedure has ceased to shed light may be quite unwarranted. Unless the subject is gradually being unfolded and developed, continuity is misapplied, for the es-

sence of research is progress, with such adaptation of the means to the stage of the investigation as necessary.

One of the constant efforts in progressive inquiry is to get away from conventions and to discover new avenues of approach, to detect new meanings, and to apply more rigorous tests of validity. It seeks evidence which is more conclusive or extends the vision, for it aims not only at confirmation but at further enlightenment. It is characterized by successive follow-up.

The more definite objective and the more direct attack of the present time, with suitable checks and refinements, have resulted in less need for the protracted type of experiments which waited long before a suggestion could be vouchsafed. With the progress made, continuity which does not yield positive results is lacking in merit, and the accumulation of data is futile unless guided by a purpose and supplying evidence which is needed.

Hence, continuation on a conventionalized plan needs to justify itself at the present stage. It is not sufficient that it is an evidence of industry and patience; continuation should imply expectations. It is important, therefore, to take frank account of stock. Workers themselves need to take a critical attitude toward their work, and administrators need sooner or later to assure themselves that the continued prosecution of a subject is proving worth while. Such work needs to be dealt with with reasonable patience, but with critical judgment based on evidence of growth.

ATTAINING THE GOAL

The understanding of a problem comes with experience in dealing with it. In a new subject research may be exploratory to uncover essentials and afford an intelligent point of departure. But sooner or later there will be developed ideas or theories which will guide the search for facts. In fields which have been more worked upon there will be a considerable basis for conceptions. Ability to grow with the research and to recognize the significance of facts disclosed is the opposite of routine. It is a means of guidance in the search for facts, and makes possible what Sir William Bragg has aptly referred to as "well-informed concentration on essential details." It is applicable in the successive stages of inquiry, and is a primary attribute of productive research.

To make experiments serve the end of disclosing essential facts, to establish the significance of each finding, and to so organize the inquiry at successive stages that it will mark progress is the ideal of research. This is difficult and often comes only after repeated attempt; it is well-nigh impossible unless there is intelligent concentration and an aiming at the things experience indicates are essential. Caution, while essential, should not reflect lack of confidence in results but rather determination to establish the facts. Hesitation to draw the lessons from the results sometimes means fear or lack of confidence in one's self.

The essential character of investigation, the fact that one can rarely go directly to the solution of a new problem but that it often must be worked out by persistent, painstaking, and often disappointing effort, requires patience on the part of the investigator not only, but on that of the general public. Expectation is born of hope, and hope is based on a confidence in science which the results of the past have justified. If the progress from fundamental research to practical results sometimes seems slow, it is to be remembered how long in the past it frequently has taken to put a newly discovered fact or principle to work. The interval has been immensely shortened in the case of agriculture, as it properly should be, for application is the outstanding objective toward which efficiency and productiveness in research are bent.

FINANCIAL SUPPORT

The funds available for experiment-station support in 1928 continued on the upward trend noted during the past few years. Most of the stations received liberal State support. There is rarely any tendency to reduce State aid because of the increase in the Federal funds.

The total funds available for station support during the past year amounted to approximately $15,040,413, of which $3,597,640 was from Federal sources and the remainder, somewhat more than $11,442,773, was from State sources. The Federal appropriations reached $70,000 for each State, or $15,000 each from the Hatch and Adams Acts, and $40,000 from the Purnell Act. This was an increase for each State of $10,000 over the preceding year arising from the Purnell Act, or a total increase of $480,000 for the country as a whole. The ap-

propriations for the support of experiment stations in the outlying territories and possessions amounted to $237,640.

The income from State sources, including appropriations, sales receipts, and miscellaneous revenues, amounted to $11,442,773.06, representing an increase of $1,455,005.74 over the preceding year and due largely to increases in State appropriations. The supplementary income of 5 stations amounted to more than $500,000 in each instance, and in the case of 14 stations it ranged from $200,000 to $500,000. Only 13 stations had a smaller income from State sources than they received from the Federal Government, and only 2 of these received less than $10,000 from sources within the States. In only 3 States was State support for experiment station work too small to be of much aid in promoting agricultural investigation.

The income of the Ohio station from State sources was reported to be $1,233,172.82, which included an appropriation of $1,058,372.65; however, due to a change in the State fiscal year, this appropriation was for a period of 18 months. The other stations reporting more than $500,000 of supplementary funds were California, Indiana, Texas, and Illinois, in decreasing order of the amounts received. The State income of 8 stations—North Dakota, Minnesota, Wisconsin, New Jersey, Michigan, Florida, Kentucky, and New York State—ranged from $459,000 to $313,000, and that of 14 stations—New York Cornell, Iowa, Nebraska, Oregon, Massachusetts, Connecticut State, Washington, Kansas, Mississippi, North Carolina, Missouri, Colorado, Montana, and West Virginia—from $295,000 to $151,000.

The supplementary funds of the experiment stations for the past two fiscal years are compared in Table 1.

TABLE 1.—*Income of the agricultural experiment stations from within the States for the years ended June 30, 1927 and 1928*

Station	1927	1928
Alabama	$64,635.91	$87,953.55
Arizona	109,535.95	129,325.79
Arkansas	80,809.72	92,632.32
California	646,184.73	785,722.73
Colorado	187,035.85	174,132.04
Connecticut State	252,864.66	210,640.02
Connecticut Storrs	53,373.92	60,640.61
Delaware	37,820.86	37,780.52
Florida	272,626.30	338,564.43
Georgia	24,779.56	63,152.87
Idaho	47,177.09	57,321.93
Illinois	494,905.50	524,317.17
Indiana	643,192.61	650,965.12
Iowa	321,851.76	283,983.95
Kansas	201,680.33	198,085.64
Kentucky	335,026.01	327,615.58
Louisiana	137,335.25	143,924.51
Maine	67,876.04	66,429.51
Maryland	133,112.89	123,247.05
Massachusetts	208,661.87	229,632.19
Michigan	342,588.77	346,584.83
Minnesota	453,745.15	451,751.08
Mississippi	132,040.47	189,357.88
Missouri	160,131.81	178,698.84
Montana	159,933.56	154,399.36
Nebraska	225,648.23	251,637.29
Nevada	8,980.14	9,119.77
New Hampshire	31,518.22	34,207.12
New Jersey	246,510.41	357,152.68
New Mexico	36,458.11	36,796.33
New York Cornell	275,391.40	295,929.38
New York State	308,940.56	313,606.63
North Carolina	77,737.00	187,122.09
North Dakota	295,086.73	459,567.21
Ohio	759,674.58	1,233,172.82
Oklahoma	49,347.90	64,090.79
Oregon	217,866.23	251,270.81
Pennsylvania	84,223.74	116,465.19
Rhode Island	4,921.22	6,367.84
South Carolina	142,564.09	141,621.75
South Dakota	93,566.52	65,757.79
Tennessee	62,882.17	57,374.27
Texas	513,716.45	600,127.52
Utah	78,382.07	89,345.69
Vermont	16,175.09	20,566.90
Virginia	113,958.34	111,655.37
Washington	185,894.14	199,165.32
West Virginia	150,137.81	151,850.06
Wisconsin	357,278.17	416,978.08
Wyoming	81,981.63	64,964.84
Total, State support	9,987,767.52	11,442,773.06
Federal funds	2,880,000.00	3,360,000.00
Grand total	12,867,767.52	14,802,773.06

Of the total supplementary funds available during the past fiscal year, $8,370,438.59 was reported for research and experiments, which was $789,176.90 more than was used for this purpose in the preceding year.

Statements of income and expenditures of the experiment stations are given in detail on pages 95–104.

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GRANTS FROM OUTSIDE SOURCES

Of recent years the funds of the experiment stations have been enlarged by grants and donations from various sources to carry out special lines of investigation or to enable the stations to take up features for which money was lacking. In the fiscal year 1927–28 such grants for research totaled $348,698. Of this amount $178,528 was

supplied by various commercial and industrial concerns, and $36,290 by industrial associations representing different commercial interests, a total of $214,818 from these two sources. This is gratifying as evidencing the readiness of business interests to aid the experiment stations in furthering their research.

A number of research institutions, such as the Carnegie Institution of Washington, the National Research Council, the Chemical Foundation, the Crop Protection Institute, and similar agencies, also aided the stations, their contributions during the year in question amounting to $15,973. Farmers' organizations, agricultural associations, chambers of commerce, and other public bodies made allotments amounting to $79,864. In addition a total of $31,290 was derived from bequests, legacies, and private endowments.

Altogether there were 155 grants reported, which were shared in by 31 stations. The amount of such grants varied in individual cases from $50 to $10,000. The largest income from this source, $73,445, was received by the New York Cornell station, and this was followed by Wisconsin with $47,055.75, Indiana with $22,700, and Minnesota with $20,804. Nine stations received $10,000 each or more. Such benefactions have, therefore, proved a considerable source of revenue to a number of the stations, enabling them to undertake investigations which otherwise would not have been practicable, at least to the same extent.

The sources of the donations from industrial concerns and their associations cover a wide range. As might be expected, these came to a considerable extent from fertilizer, insecticide, fungicide, food, baking, dairy products, farm-machinery, incubator, and canning industries, but there were contributions from brick manufacturers, chemical and fermentation industries, nurseries and bulb growers, forestry and lumber interests, meat packers, and sugar producers. Electric-power and equipment companies and other public utilities made a total of 14 grants, mainly for experiments in the utilization of electricity on farms and in connection with agricultural operations. There also were grants from sauerkraut packers, flax development organizations, the United States Golf Association, the Horse Association of America, the Kentucky Jockey Club, dairy-cattle associations, and the Outdoor Advertising Association.

One conspicuous instance of aid to research was that by the Wisconsin Manufacturers' Association, which has placed at the disposal of the Wisconsin experiment station a grant of $10,000 a year for a period of five years for research on contagious abortion in dairy cattle. This action was the result of the association's interest in the agriculture of the State and the desire to assist the station in an important line of work. The subject was chosen by the station, and the funds are being devoted to a study of the relation of the plane of nutrition of dairy cattle to susceptibility to the disease, which is a serious menace to dairying.

COOPERATIVE RESEARCH WITH COMMERCIAL AGENCIES

The broad question of private aid to public institutions is one of importance, and certain aspects will need to be considered with some care if substantial endowments of the State experiment stations become at all numerous. That the interests and responsibilities of the stations is being conserved in this matter is shown by the attention given to it by the Committee on Experiment Station Organization and Policy of the Association of Land-Grant Colleges and Universities.

As that committee pointed out,[2] the establishment of the agricultural experiment stations as publicly supported research institutions was based upon the premise that the results accruing from research in the field of agriculture benefit all society. That this premise is correct has been amply demonstrated by the broad application that has been made of the results of such research. Since research in this field benefits all society, it should be supported, not by a single class or by a few groups of especially interested classes, but by society as a whole.

When public funds are not available for the conduct of research of a special character for which there is urgent and immediate need, private grants from commercial agencies may make possible the securing of prompt results and thus serve both these interests and those of the public.

There is ample evidence that experiment stations and the farmers whom the stations serve have profited materially by contacts and cooperation

[2] Association of Land-Grant Colleges and Universities. Proceedings of the forty-second annual convention . . . held at Washington, D. C., November 20–22, 1928, p. 204. Burlington, Vt. 1929.

with commercial enterprises and interests. Hence, the committee considered that under certain definite limitations and conditions it is proper for the experiment stations to accept grants for agricultural research from such agencies. The following general conditions were laid down as the basis for a broad policy:

> The research supported in this way should be of general public importance and in the field of the agricultural experiment station.
>
> All such researches should be institutional and not cooperative with individual departments or staff members, and salaries and other expenditures should be handled through regular institutional channels.
>
> Carefully worded project agreements should be drawn, setting forth the nature and purpose of the project, and the conditions under which the grant is accepted and is to be used. In this the interest of the station and of the public should be safeguarded in the same way as research under other station funds, and the right to patent any discovery be reserved to the institution.
>
> Results should first be made public through the regular station channels, whether favorable or unfavorable to the cooperating agency.

It is quite evident that each new proposal will need to be considered on its own individual merits to ensure that there is involved neither direct nor indirect interference with their complete and impartial functioning as fact-finding and truth-revealing public agencies.

GIANNINI FOUNDATION

Notable among the private benefactions to agricultural research, in addition to those noted above, was the contribution of $1,500,000 to the University of California to be used for the establishment of the Giannini Foundation of Agricultural Economics. The donation was made by the Bancitaly Corporation of San Francisco in tribute to its founder and president, A. P. Giannini.

The activities of the foundation will be devoted to the field of agricultural economics, particular mention being made in the offer of the economic consequences of increased production resulting from improved agricultural practices; the economic consequences of overproduction; the relations between conditions in the farming industry and general economic conditions; the acquisition of knowledge on soil and climatic conditions and on the economic status of California farm products to enable foundation representatives to advise California farmers on agricultural practice; methods and problems of disposal of farm products; and any economic questions concerning the farmer and his family.

The primary function of the foundation, according to the terms of the offer, is to be that of a research agency with the purpose of finding the facts and conditions which will promise or threaten to affect the economic status of California farmers. It also proposes to develop ways and means for enabling the farmers of California to profit from favorable facts and conditions and to protect themselves as well as possible from adverse facts and conditions.

In order to provide a suitable building for the foundation, a provision was included that not to exceed $500,000, or about one-third of the total gift, is to be used by the regents for the construction and equipment of a new Giannini Hall. Funds for this building were to be made immediately available.

No specific restrictions are imposed on the university, except that in selecting members of the staff of the foundation the regents were requested to seek and appoint the most competent persons whose services are available, without restriction as to citizenship or race. It was suggested that any teaching activities necessary in connection with the work be provided for largely, and if practicable wholly, from funds available from sources other than the foundation. The foundation constitutes a part of the college, and the fund will be used in intimate association with other funds of the college and experiment station.

FACILITIES FOR RESEARCH

The growth of the agricultural colleges in recent years has taxed severely the accommodations and facilities at their disposal. Buildings and quarters formerly regarded as ample have become inadequate or unadapted to present needs. This situation has been reflected in the experiment stations, which have had such notable expansion under the Purnell Act. In some instances the development of new departments and the inauguration of new lines of study have been contingent upon additional quarters and special equipment.

The States are relied upon to supply the buildings and other features of the permanent plant. This is one of their contributions to the experiment station enterprise, as the Federal funds are intended primarily for the current expenses of research and are available

only to a very limited extent for construction. While naturally there has been delay in some cases, in general the States have realized their responsibility and are responding generously to the enlarged need. The disposition to deal liberally in the matter of providing equipment and facilities is evident from recent building programs and from provisions made for various overhead expenses of the stations.

Facilities for station research were improved in a number of noteworthy ways during the year. Besides profiting by the general building programs of the institutions as a whole, the stations expended for buildings and equipment out of their own specific resources $1,528,610.44, the main items of expenditure for this purpose being buildings, $799,475.10; farm implements $216,902.19; livestock, $146,495.17; apparatus, $165,182.10; library, $71,683.63; and miscellaneous, $128,872.25.

BUILDINGS

In the construction and equipment of new buildings provision is being made to an increasing extent for experimental work which requires absolute control of conditions and environment. This is a result of the constant trend of station work toward fundamental studies of causes. A striking example of such provision for controlled investigation is furnished by the plant industry building of the University of Minnesota, built and equipped at a cost of $250,000 to house and provide for the instruction and research of the division of agricultural biochemistry. The first floor of this building is entirely devoted to experiment station work, and provides complete and modern equipment for biochemical research. Facilities for research are provided also in other parts of the building. Similarly, the new agricultural building of the University of Arkansas, constructed and equipped at a cost of $300,000 and occupied during the year by several departments of the station, is provided with improved facilities for research.

The University of California began the construction of a $500,000 building primarily for the provision of offices and other facilities for the Gianinni Foundation of Agricultural Economics previously mentioned. This building, known as Gianinni Hall, and completing the agricultural quadrangle of the College of Agriculture, will be available in part also for other purposes. The Indiana station included in its improvements a new agricultural engineering building costing $78,000, and the Kentucky station prepared plans for an agricultural building to cost $150,000.

The Pennsylvania college constructed a hospital and infirmary at a cost of $150,000, half the amount being the gift of the State Potato Growers Association in appreciation of the benefits derived by the potato industry of the State from the work of the college and station. For other buildings this institution received an allotment of $200,000, of which $150,000 was for the erection of the first unit of a biology building.

The South Dakota college, in a new chemical laboratory building to cost $60,000, set aside a section for the work of the station chemist. The Georgia station completed a 3-story fireproof office and laboratory building costing $65,000, and the Mississippi station received a State appropriation of $100,000 for an administration building.

The University of Tennessee, with an appropriation of $2,500,000 available in five equal annual installments, inaugurated a building program with a physics and biology building to cost $300,000 when equipped. It also planned the construction of a chemistry building.

The Connecticut college at Storrs had under construction during the year a general-science building to cost $450,000. While these buildings are for general university and college use, they are expected to aid materially in furnishing better facilities and equipment for station work.

Improvements for the advancement of studies in animal husbandry were reported by a number of stations. Important additions facilitating the work of the California station are provided in the animal-science building at Davis, which was completed during the year at a cost of $300,000. The Pennsylvania college and station expended $50,000 for additional buildings, including a sheep barn with a wool-grading room, a livestock hospital for the study and treatment of animal diseases, and the first unit of a poultry plant. The Indiana station provided an equipment building and water system for its animal-husbandry farm, and the Ohio station occupied a new animal-husbandry building constructed at a cost of $75,000.

Facilities for dairy work were increased at the New Mexico station by

a new dairy building with laboratories and modern equipment, and at the Arkansas station by a tile barn built on the station farm representing a unit-type plan designed by the department of agricultural engineering. In the new $500,000 dairy building of the Iowa college and station the upper floor of the main structure is devoted entirely to dairy bacteriology and other dairy research, the second floor contains laboratories for farm-dairy and milk-testing work, and the lower floor is occupied, in part, by a research laboratory for dairy engineering. A new dairy barn to cost $100,000, under construction at the Michigan station, is to be restricted to cattle found free from all symptoms of contagious abortion. The Wisconsin station has added a concrete milk house to its equipment for the better handling of milk in its dairy studies.

Approximately $70,000 was used at the University of California for the construction at Berkeley of a new poultry husbandry research plant, including a laboratory building and various types of poultry houses. The Indiana station added a pavilion and three laboratory rooms to its poultry-husbandry equipment, the Michigan station made preparations for the construction of a poultry plant to cost $50,000, and the North Carolina station also provided for the improvement and enlargement of its poultry plant during the year.

Other new buildings and improvements included an agronomy laboratory erected by the Ohio station at a cost of $25,000, and a wing to the horticultural building at the University of Florida which was completed at a cost of $125,000. The new horticultural building of the Arkansas station, constructed last year, was equipped for the grading and packing of fruits; and the office and laboratory building erected at the Georgia station was provided with cold-storage facilities for the handling of fruits and vegetables. The Iowa college and station expended approximately $110,000 for an agronomy laboratory, a horticultural seed house, an insectary, and a veterinary research laboratory with isolation units; while the Mississippi station received appropriations of $5,000 for a cotton gin and warehouse and $10,000 for repairs to barns and fences.

EQUIPMENT

A fact not always appreciated is the special equipment essential to the promotion of the type of research required at the present time. Crude facilities and makeshifts no longer will suffice, and the refinement of methods and development of technic call for many special types of buildings and fittings. One of the most frequent deficiencies is the lack of greenhouse space suited to the varying needs of research. Such facilities are a prime necessity, and such installations often must be provided with devices for controlling various features such as air and soil temperature, humidity, intensity and color of light, and other factors that have a bearing on plant development.

Greenhouses for experiment-station work must be capable of adaptation to special investigations and purposes; and such equipment, when efficient and adequate, makes it possible to carry on plant breeding and other work the year around, to hasten the development of new varieties, to make quickly and accurately tests for winter hardiness, and in general to conduct a class of work requiring control of the several factors entering into the various problems. Without facilities of such character the experiments and investigations can not advance very far, and the work is likely to be limited to repetition under local conditions and to trials which give only empirical results.

Definite progress along these lines was reported during the year by a number of institutions. The Minnesota station added eight units to its greenhouse equipment, to be used in research in plant genetics, plant physiology, plant pathology, and farm crops. The artificial lighting provided permits plant growth to proceed in and out of season. The Oregon college expended over $60,000 for new modern greenhouses in which the experiment station has the exclusive use of 6,600 square feet and part use of an additional 3,300 square feet.

The Washington station completed the first unit of a new range of greenhouses for experimental work in plant pathology and agricultural bacteriology. The Indiana station, at a cost of $12,000, completed a new greenhouse with a series of controlled-temperature rooms. The Florida station, likewise at a cost of $12,000, erected a greenhouse at the Everglades substation. The Mississippi station received an appropriation of $5,000 for two greenhouses for experimentation in agronomy and horticulture. The Ohio station devised apparatus for

the study of ventilation, humidity, and temperature control in greenhouse management.

Many of the improvements made by the experiment stations have resulted in the refinement of methods, reduction of time and labor in making determinations, and greater accuracy in the results. The New Jersey stations, to obtain more reliable data on the relative effect of variable and constant temperatures on the development of insects, constructed a piece of apparatus in which temperature, moisture, and light are under control. The elimination of the variables other than temperature permits direct experimentation with a controlled constant or a controlled variable temperature, held at any point within or confined to the range of active temperatures of the particular insect studied. The Florida station also had under construction a constant-temperature apparatus for insect life-history studies.

The Pennsylvania station, by modifying an apparatus used in determining urea in blood, reduced a frequent error of several milligrams to within 0.1 milligram of urea nitrogen in a 100-cubic-centimeter sample, and also made it possible to obtain very satisfactory results with as little as a 0.1-cubic-centimeter sample of whole blood. The home economics department of the Maine station equipped a new chemical laboratory for use in iron analysis of foods and for adaptation later to investigations in human iron metabolism. To avoid possible interference with the analytical results the piping and fittings used were of brass, and all equipment generally was made either of iron substitutes or of iron unexposed.

The nutrition laboratory of the New Hampshire station was enlarged to house the offices and laboratories in animal nutrition, including metabolism stalls and respiration chamber and the laboratory for studies in human nutrition. For the animal-nutrition studies the respiration chamber was improved to permit experiments to be carried on for any length of time and the animals to be fed and watered and cows to be milked and fed at regular intervals during that time; to permit the regulation of environmental temperature; and to permit the determination separately of metabolism during standing and lying. An apparatus was perfected also for the separate collection of urine and feces from cows. This station is further taking advantage of apparatus developed by the nutrition laboratory of the Carnegie Institution. An apparatus for gas analysis as a means of indirect calorimetry has increased the speed of absorption and the accuracy of determination, and its electrical operation makes it possible for one analyst to run two units at a time. Another apparatus used in studying the energy metabolism in sheep is based on the principle of collecting from the ventilating current of the respiration chamber a representative aliquot sample of air in which the percentage of oxygen and carbon dioxide is determined by analysis. A simple and efficient metal pump for collecting the air samples eliminates the use of mercury and avoids the breakage incident to the handling of glass samplers. The station also adopted dry ice or solidified carbon dioxide as a laboratory refrigerant, especially in experiments to determine the hardiness of the apple and other orchard trees. The method, as developed, makes it possible to reach and maintain temperatures as low as —40° to —50°.

The Connecticut Storrs station developed a device facilitating the feeding of hay to cows under experiment by limiting an individual portion to each animal, thus assuring accuracy and controlling waste.

At the Tennessee station a new lysimeter installation, completed and put into operation during the year, has a capacity of 149 tanks, embodies ideas and improvements made since the station's original equipment was installed, and constitutes one of the most complete, efficient, and adaptable lysimeter installations ever constructed. The South Carolina station installed a series of test plats with uniform soil throughout, and with each plat surrounded by a concrete wall. At the New Jersey stations additional laboratory facilities were provided under a State appropriation of $10,000 for nutrition laboratories and one of $15,500 for sewage laboratories.

LAND

The States have continued to provide the stations also with additional land for experiments, and to establish substations and other outlying activities where needed. In some instances land and equipment were donated by individuals. The Cornell experiment station participated in the use of a tract of 500 acres of abandoned farm land given for experiments and in-

struction and as an observation ground for botanists. The development of the Arno Forest of 1,850 acres, given to Cornell University about a year ago, was carried forward, and experiments were begun to test thinning and cutting methods.

The Arkansas station put into shape for crop rotations and other agronomic experiments a 100-acre addition to the station farm, and made progress in the construction of buildings and equipment at the three substations recently established, for which approximately $30,000 was available at each place. The planning and construction of the buildings and other improvements was under the supervision of the department of agricultural engineering of the station.

The Illinois station acquired 208 acres at a cost of $62,400 for the use of the dairy, agronomy, and animal husbandry departments; and the Mississippi station received, among other State appropriations, $20,000 for additional land for the departments of animal husbandry and horticulture. The New Mexico station added 13 acres to its horticultural farm, and the Rhode Island station purchased 45 acres of upland farm land for extending its work in pomology and poultry husbandry.

The Alabama station was authorized by the State legislature to establish five substations, two to be started in 1928, one in 1929, and the others in 1930. An appropriation of $25,000 was made for equipment, and $12,500 annually for maintaining each substation. The communities where these substations are to be located are expected to provide at least 200 acres of land for their use. The first substation was located during the year at Belle Mina in the northern part of the State; the second was to be located in the southern part of the State during the summer of 1928. The Louisiana Legislature, in 1928, passed an act providing for the establishment of a substation at St. Joseph in the delta section of the State, which is to give attention mainly to work relating to cotton production.

A farm of over 700 acres near Kalamazoo was dedicated to the Michigan college for experimental purposes, and in addition the institution received an endowment of $180,000 for research. The Michigan station selected a site near Bay City for a potato experiment station, for which the legislature appropriated $25,000 a year ago. The appropriations of the Mississippi station for the substations included $8,000 for the purchase of additional land at Holly Springs, $7,500 at Poplarville, and $5,300 at Stoneville. This station also was given $25,000 by Adams County for the purchase of land and equipment for the permanent substation for pecan investigations and other work for which the State already had made an annual appropriation of $15,000.

The South Carolina station, under an appropriation of $25,000 for the sand hill substation, let contracts for an office and laboratory building to cost $14,000.

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EXTENSION OF EXPERIMENT STATION ACTS TO HAWAII

By an act of Congress approved May 16, 1928, the benefits of the Hatch, Adams, and Purnell Acts were extended to the Territory of Hawaii and appropriations were authorized, beginning with the fiscal year 1930. The legislation provided that the amounts carried by these experiment station acts shall be available on a progressively increasing scale, as they were in the case of the States.

The initial appropriation of $15,000 will correspond to the Hatch fund; that for the second year will include also the first installment authorized by the Adams Act ($5,000), the amount increasing annually until the full appropriation of $15,000 under the Adams Act is realized, in 1936; and following that year the additions provided for by the Purnell Act will be available, beginning with $20,000 and increasing by $10,000 annually. Under this plan the station in Hawaii would receive the full amounts authorized by the three acts in 1941, continuing thereafter to receive the same amounts as do the States.

These grants are in addition to the appropriations to the Department of Agriculture for use in Hawaii, where it has conducted an agricultural experiment station since 1901.

In recognition of this, it is provided in the new act that the experiment station established under it shall be conducted jointly and in collaboration with the existing Federal experiment station in enlarging and expanding the work of the latter on cooperative plans approved by the Secretary of Agriculture. The new Territorial station will be connected with the college of agriculture of the University of Hawaii.

SUSPENSION OF FEDERAL FUNDS

Two cases arose during the year in which it was found necessary to suspend payment of the Federal appropriations. In one case these were restored after a few months, and in the other the certificate of the department awaited congressional action. Under the provisions of the Federal acts these cases are to be reported on, with the reasons for the action taken.

RHODE ISLAND EXPERIMENT STATION

Difficulties in connection with the local administration of the Rhode Island station, extending over several years, reached a crisis which necessitated the department's action.

During 1927 evidence increased of lack of adequate supervision of the research program in part, and of disposition to disregard administrative requirements with respect to projects and funds which apply to all of the stations alike. The continued approval of expenditures and assignment of funds for certain projects quite unwarranted by their progress and outlook, led to questions of legality in the use of the Federal funds, and indicated that these were not being properly safeguarded. Furthermore, insistence on outlining and interpreting projects in such broad and vague terms as to make it impossible to judge of their merits or to identify the work under them led not only to further questions regarding expenditures, but tended increasingly to nullify the department's supervision and to weaken the administrative confidence on which it rests.

Attempts through several months of correspondence to clarify the situation, to ascertain the status of work on projects in question, and to arrive at a basis for settlement of the previous year's account met with slight cooperation, and finally left no course open than action looking to the suspension of funds. This was a last resort, as the station is without regular State appropriations and consequently is dependent on the Federal funds. Notice of the proposed suspension failed to bring favorable action, and hence the third quarterly installment, due January 1, 1928, was withheld. As further delay ensued, the fact of the suspension and the reasons therefor ultimately were reported to the college authorities.

The latter relieved the director of administrative responsibility and appointed an acting director, who immediately took up negotiations. The requested information was supplied quite promptly, an understanding was reached on the working program and the budget for the year, and a basis was provided for settlement of the financial account for the previous year involving a disallowance of some $3,000. The Federal funds then were restored, and the station suffered no financial loss except the disallowance mentioned. It was duly certified for the appropriations beginning July 1, 1928.

OKLAHOMA EXPERIMENT STATION

The Oklahoma station suffered another upheaval near the close of the fiscal year 1928, so unwarranted and so disastrous as to make the institution an unsafe place to intrust funds for research until conditions were remedied. Without notice, the director and several members of the station staff, with a number of the college faculty, were dropped. The result was such a feeling of instability that half a dozen other station people withdrew at the first opportunity.

The action of the board came at a time when the college was without a president and carried with it the dean of agriculture. It was taken without the advice of administrative officers. No charges or opportunity for hearings were presented, and no reasons for the dismissals vouchsafed. It left the station, which had been progressing remarkably well, in a seriously crippled condition. The failure to comprehend the damage which such arbitrary action would inflict on a research institution was an evidence of irresponsibility.

The instance was a repetition of disturbances which have occurred at frequent intervals in the past, and have given the Oklahoma college and station a conspicuous record for instability. The average term of office for the college president has been about four years, and that for the dean and director somewhat less. The present change in directorship was the eighth since 1900. Positions on the staff have been equally temporary; since 1900 there have been upwards of 100 separations, a large proportion of them persons occupying prominent places in the work. Those not due to dismissal were attributable in large measure to lack of confidence in the security of position and opportunity for completing work.

No experiment station could withstand such unfavorable conditions without serious effects. Research suffers more severely from instability and frequent changes than does any other branch of the college. In this case the removal of key men, with the disruption of investigations and interference with established programs of research, have resulted in large waste of money and effort, and made it difficult to secure and hold competent investigators. In the latest instance practically every project was affected; in a number of cases important data were sacrificed, and in others the work remained practically at a standstill or suffered a setback.

The difficulty from which the station has suffered so long seems inherent in the provision for the government of the college. Under the State constitution the State board of agriculture is constituted the governing body of the college, along with performing the customary functions of such boards relating to the agriculture of the State. This board is composed of a president, elected by popular vote, and four members appointed by the governor, subject to change by him and with the State administration. Hence there is lack of any provision for continuity so important in the management of an educational institution. Membership is limited by law to actual farmers, but there is no qualification pertaining to familiarity with educational affairs.

In the light of experience, the inadequacy of the present provision has been recognized, and for some time there has been a movement under way looking to the provision of a separate board for the college, specially selected for the purpose and with terms of office which would give continuity to the governing body. This seems highly important, for until it is possible to secure the establishment of fundamental policies and recognition of the principles essential to success in research, the evidence is that no permanent measure of relief can be insured.

PERSONNEL OF RESEARCH

The relatively large number of important changes in station personnel, which occurred during the year, included several directors and a number of leaders in important lines of research. On the whole, however, the station personnel is being strengthened progressively through encouragement of those in the lower ranks to prepare themselves for higher positions by advanced study, assurance of security in position during efficient service, salary commensurate with a just appreciation of the work, and satisfactory working conditions. Despite sporadic manifestations to the contrary, tenure of position and freedom from uncertainty as to it is generally recognized as one of the prime essentials of effective station work.

The principle of equal pay for equal service as between college and station employees has been approved by the Association of Land-Grant Colleges and Universities and adopted by many of the land-grant institutions, not only as a matter of equity, but as an encouragement to and recognition of research. This involves recognition of the additional months of service generally required of station workers as compared with those who have only teaching duties in the regular college year. It is realized that since research is a paramount type of activity making unusual demands, and creative ability in it is a relatively rare quality, outstanding figures in that sphere should be rewarded on the basis of their accomplishment and promise, rather than their advancement be dependent upon attaining administrative position.

Until the agricultural colleges and experiment stations recognize research and reward it for itself, as some of the older universities are beginning to, the more fertile imaginative minds will not be attracted permanently to that field. Here, at least, the flat salary scale is a handicap, which those in authority should be permitted to throw off in recognizing special ability and making the outlook attractive for a research career.

CHANGES IN DIRECTORSHIPS

There was an unusually large number of changes in directorships during the year.

W. R. Dodson resigned as director of the Louisiana stations and was succeeded by C. T. Dowell, formerly director of the Oklahoma station.

V. R. Gardner, head of the department of horticulture of the Michigan station, was made director of the station, succeeding in this position R. S. Shaw, who was elected president of the college.

W. W. Burr succeeded to the directorship of the Nebraska station upon the election of E. A. Burnett as chancellor of the university.

F. B. Morrison, director of the New York stations, resigned to become head

of the department of animal husbandry at Cornell University and was succeeded at the New York State station by U. P. Hedrick, formerly vice director. In addition to his duties as dean of the college of agriculture, A. R. Mann was made director of the New York Cornell station.

F. J. Sievers, head of the department of soils of the Washington station, succeeded S. B. Haskell as director of the Massachusetts station.

C. E. Sanborn was made acting director of the Oklahoma station following the withdrawal of C. T. Dowell as director.

B. E. Gilbert, chemist of the Rhode Island station, was appointed acting director in place of B. L. Hartwell.

B. Youngblood, director of the Texas station, resigned to take up work in the Department of Agriculture, and was succeeded by A. B. Conner, formerly vice director of the station.

P. V. Cardon, farm economist of the Utah station, was made director of the station, succeeding W. Peterson, who continued as director of extension.

H. G. Knight resigned as director of the West Virginia station to become chief of the bureau of chemistry and soils of the Department of Agriculture and was succeeded by F. D. Fromme, plant pathologist of the Virginia station.

OTHER CHANGES

Approximately 68 major changes were made in the general personnel of the stations during the year. Of these 38 occurred among the heads of departments or leaders in different lines of work and 30 in the rank of associates.

Some of the more important changes in heads of departments and leaders in important lines of work were as follows:

Louise P. Glanton was appointed head of home economics in the Alabama station, succeeding Agnes E. Harris, resigned. N. B. Guerrant was appointed research associate in animal nutrition.

Mrs. Henrietta K. Burton succeeded Helen C. Goodspeed as head of the department of home economics of the Arkansas station. Barnett Sure was made head of the department of agricultural chemistry.

J. B. Kendrick was appointed associate plant pathologist of the California station. G. D. Turnbow, acting head of the department of dairy industry, and A. W. Christie, associate chemist in horticulture, resigned.

L. C. Dunn, poultry geneticist of the Connecticut Storrs station, resigned to accept a position in the department of zoology at Columbia University.

G. L. Schuster, agronomist at the Delaware station, was granted leave of absence for graduate work at Cornell University.

O. F. Burger, plant pathologist of the Florida station, died as a result of accident, January 26, 1928. J. L. Seal was appointed associate plant pathologist.

K. T. Holley was appointed associate chemist at the Georgia station.

R. H. Engle succeeded Harrison C. Dale as agricultural economist of the Idaho station. C. E. Lampman was appointed poultry husbandman vice R. T. Parkhurst, who resigned to become director of the International Institute of Poultry Husbandry at the Harper Adams Agricultural College in England. Ella Woods was added to the staff as research home economist. Hobart Beresford was made head of the division of agricultural engineering, succeeding M. R. Lewis, resigned.

M. H. Campbell was appointed associate in dairy husbandry, and W. S. Brock, assistant chief in systematic pomology, at the Illinois station. H. J. Snider, assistant chief in soil experiment fields, was granted a year's leave of absence for graduate work.

Laura I. McLaughlin was made director of research in foods and nutrition at the Iowa station. F. B. Smith was appointed assistant chief in soil chemistry and bacteriology vice E. V. Abbott, resigned. J. M. Shaw, assistant chief in dairy husbandry, and L. W. Erdman, assistant chief in soil bacteriology, resigned.

L. E. Melchers, head of the botanical work of the Kansas station, was granted a year's leave of absence to engage in special work in plant pathology for the Egyptian Government. Millard Peck, in charge of investigations in land economics, and A. H. Helder, in charge of landscape gardening, resigned. The latter was succeded by L. R. Quinlan.

A. M. Peter retired as head of the chemical department of the Kentucky station, continuing his connection with the department in a consulting capacity. J. S. McHargue was made acting head of the department. A section of animal nutrition was created in the department of animal husbandry with G. D. Buckner in charge. Fordyce Ely, formerly of the Iowa station, was made head of the dairy department.

C. I. Bray, formerly of the Colorado station, was appointed head of the department of animal industry of the Louisiana stations. F. C. Old, head of the poultry husbandry work, and J. F. Brewster, research chemist in sugar work of this station, resigned.

A. C. Hildreth, formerly of the Minnesota station, was appointed associate biologist of the Maine station for special investigations on the blueberry.

A. G. McCall, head of the department of soils of the Maryland station, resigned to become head of the soils work in the new Bureau of Chemistry and Soils of the Department of Agriculture. P. W. Zimmerman, botanist and plant propagator of the station, resigned.

A. J. Patten, for 22 years chemist of the Michigan station, resigned. J. F. Cox, head of the farm crops department of the station, was made dean of agriculture, and H. C. Rather succeeded him as head of the farm crops department. J. T. Horner, research economist, was granted a year's leave of absence for advanced study.

J. D. Black, chief of the division of agricultural economics at the Minnesota station, resigned to accept a position in Harvard University, and H. B. Price was made acting chief of the division. O. G. Schaefer, associate dairy husbandman, resigned.

D. C. Neal, plant pathologist of the Mississippi station, resigned to accept a position with the Department of Agriculture. W. T. Mallory was appointed to have charge of pecan investigations, and D. S. Buchanan succeeded C. J. Goodell in the department of animal husbandry.

Richard Bradfield, associate in soils at the Missouri station, was granted leave of absence for foreign study.

C. N. Arnett, head of the animal husbandry department of the Montana station, resigned, and was succeeded by H. W. Vaughan, of the Minnesota station. Clyde McKee, agronomist of the station, was made also vice dean of agriculture.

V. E. Spencer, formerly of the Illinois station, was appointed associate in soils research at the Nevada station.

Mary E. A. Pillsbury, research specialist in nutrition at the New Hampshire station, resigned. Walter Wisnicky was appointed poultry pathologist.

R. L. Starkey was appointed associate microbiologist at the New Jersey stations, and Daggmar H. Peterson, research zoologist in sewage investigations, resigned.

John R. Eyer was appointed entomologist of the New Mexico station, vice F. M. Hull, resigned.

H. H. Wing, head of the department of animal husbandry of the New York Cornell station, retired at the end of the school year, 1927–28, after 40 years of service, and was made emeritus professor. He was succeeded by F. B. Morrison.

R. J. Anderson, chief in research in biochemistry of the New York State station, resigned to accept a position at Yale University. R. L. Shriner, associate in research biochemistry, resigned. D. C. Carpenter, associate chemist, was granted a year's leave of absence.

J. H. Beaumont, formerly of the Minnesota station, was appointed head of the department of horticulture of the North Carolina station, succeeding C. D. Matthews, resigned. R. S. Curtis, animal husbandman, resigned.

Paul Gerlaugh was made chief of the division of animal industry of the Ohio station, succeeding G. Bohstedt, who went to the Wisconsin station. E. E. Barnes was made associate in agronomy.

At the Oklahoma station, F. Griffee, plant breeder, resigned to accept a position at the Maine station, and W. W. Fetrow, agricultural economist, and J. O. Ellsworth, associate in farm management, resigned. Marjorie P. Benoy was appointed associate in home economics research, and J. F. Page was made associate rural sociologist, succeeding L. D. Howell, resigned.

S. W. Fletcher, horticulturist of the Pennsylvania station, was made director of research in agriculture.

J. C. Weldin was appointed chief in animal breeding and pathology at the Rhode Island station. E. S. Garner was appointed agrostologist, and J. L. Tennant, associate agricultural economist.

A. H. Meyer was made associate agronomist of the South Carolina station.

M. D. Farrar, apiculturist, and C. F. Wells, chemist, of the South Dakota station, resigned.

H. P. Traub, formerly of the Minnesota station, was appointed head of the division of horticulture of the Texas station. W. N. Ezekiel was appointed plant pathologist, and C. A. Bonnen research specialist in farm management.

J. A. Geddes was appointed sociologist and F. B. Wann associate botanist of the Utah station.

Marianne Muse was put in charge of home-economics research at the Vermont station.

T. K. Wolfe, agronomist of the Virginia station, resigned, and was succeeded by N. A. Pettinger. Ilena M. Bailey succeeded Ellen A. Reynolds as home economist of the station.

At the Washington station, J. R. Magness, of the Department of Agriculture, was made head of the department of horticulture, H. A. Bendixen associate in dairy manufactures, L. A. Black associate in dairy bacteriology, and L. E. Miles, formerly of the Alabama station, associate plant pathologist. E. G. Schafer was made head of the consolidated soils and farm-crops work of the station.

G. Bohstedt, formerly of the Ohio station, was made animal husbandman of the Wisconsin station. H. C. Jackson was made head of the dairy husbandry department, succeeding E. H. Farrington, who was made professor emeritus. G. S. Wehrwein was appointed to have charge of research in land economics.

THE POINT OF VIEW

Upon the selection and development of the personnel will depend in a very large measure the success of the experiment station and the character of the work done. Given proper organization and administration, the glory of its achievement will depend on those who work there. This is acknowledged in principle, but it is not always expressed in practice. The standards on which the selection of the personnel is made are not always very exacting or representative of the station's requirements. As a result, not all of our experimenting is on problems; considerable of it is with men and women brought into the research staffs.

The problem of more fundamental research in agriculture is in very large measure a matter of the point of view. A primary object of research is the ability better to understand — not merely to get a superficial view, a temporary or limited comparison, or empirical facts which are good only for the time and place; but facts which are sufficiently basic and understood to be reasoned from.

This calls increasingly for trained investigators, with the research type of mind and the originality and imagination to visualize the essential nature of problems, and then to devise the way they must be studied to get more definite answers. In order to advance, it often is necessary to break away from the conventional or customary way of thinking and working on a subject, and to develop new ideas. Such new conceptions are the basis of progress in research—the ability to look beyond what others have done or proposed and to devise means of getting at the more fundamental aspects of the subject. For the underlying object of research is not merely to assemble more data but to find new meanings. As has been said, a better knowledge of a subject will not come from the mere multiplication of men able to collect more facts, but from the increase of those who know what facts need to be collected and the value of these facts when they are established.

Before a new thing can be done or an idea put into action, it is necessary to conceive of the possibility of doing it and then to conceive the means by which it may be done. This requires the student who will extend his thinking and his search beyond the obvious and beyond the immediate application.

So much stress has been laid on the practical aspects of problems and their answers that it has sometimes affected the working program and misled those employed to carry it out. Practical knowledge is not to be minimized—to be useful is the underlying purpose, but knowledge is not less useful because it is scientifically sound and it is not less practical because the principles on which it depends are understood. A worker may be so practically minded as to see only the immediately practical aspects of the question before him, and in his haste be satisfied with a type of work which gives results of doubtful breadth or stability. This point of view may be so strong as to motivate all his activities and limit his aspirations.

Too close concentration on immediately practical ends may stifle the interest in real research. Frequently it has been so overbalanced as to prevent that interest from being aroused or a vision acquired which reached beyond superficiality.

DISCRIMINATION IN STAFF

One of the things needed as the station work advances is sharper distinction between those on the station staff as to their qualifications for research and the extent to which they may be entrusted with research projects. This must be based more largely on accom-

plishment as evidencing native ability, trained preparation, and experience.

One of the greatest drawbacks to productive research is the advancement of immature and unqualified workers to positions of responsibility. A premium might well be put on proven ability, and growth and accomplishment established as prerequisites of advancement. The type of persons needed for the station investigation will not be secured in sufficient quantity unless the necessary requirements are set up and maintained. In the absence of this there is bound to be a considerable measure of immature and even abortive work. Many recruits, especially in the newer lines, need a period of work under guidance and supervision—a "trial by fire," before they can profitably be given independent responsibilities.

There is evidence that in the rapid expansion men and women are being brought in and given responsible charge of investigation before they are prepared to exercise it. This is shown by the projects set up and by the work done. They are learning at the expense of the stations, in the school of everyday experience. They are becoming acquainted with the meaning of research and getting an introduction to problems and the means of studying them after they have been placed in positions which call at the outset for the exercise of such knowledge. Often the background to be acquired by them is quite elementary in character, and it is an expensive and time-consuming process for the station. These things are properly a part of the fundamental preparation for such a career, in the advanced courses which introduce the student to research and enable him to find himself.

While there has been general improvement in the grade of qualifications of workers, in some notable cases the requirements have not advanced to the degree that might be expected at this juncture. This is not confined merely to the newer lines where the supply of qualified workers has been severely taxed, but is exemplified in the older fields as well, where there is less justification.

ORGANIZATION AND ADMINISTRATION

Effective organization with provision for adequate administration is no less essential in a research institution like the experiment station than in any other large enterprise. This is being realized to increasing extent and becoming more important in the station management with the growth in size and complexity. For the experiment stations have become relatively large units in the agricultural colleges; they draw their forces from various parts of these institutions; and they employ facilities in common with other branches of them. They stand for a directed type of effort, dealing with problems whose complexity is increasingly evident, and they are expanding into new fields.

This expansion requires much more than the mere establishment of new departments, for the new branches and the problems with which they are concerned must be knitted into the fabric of the existing organization. They have many important relationships to the older features, and in many respects will require larger attention for the present than some of the longer-established lines.

Naturally administration must apply to the experiment station as a whole, and not leave new and unfamiliar parts to work out their own destiny. Preparation for such administration has only been made in part. To strengthen and enlarge it in an effective way is an essential measure for growth.

STATION UNITY

The idea of the unity of the station is one which grows in importance with the enlargement of the field of research and the plans for more fundamental study of leading problems. The station originally was designed as an organized research agency. The Hatch Act was clear on that point; it called for the establishment within the college of "a department to be known and designated as an agricultural experiment station." All of the State stations were organized or reorganized under that act. This idea has been perpetuated in succeeding legislation.

Under that conception the experiment station has a field of its own, and an individuality which needs to be preserved. Within the college and to the general public it stands for a special type of effort, it has a special responsibility, and it has a clientele which if cultivated may become a source of material strength. Hence it is clearly not an unrelated group of persons, each working independently on what interests them most; it is a united body with common interests and responsibilities, conducting their investigations in accordance with an accepted general program determined upon advisedly after careful considera-

tion. This conception implies on the part of the staff a consciousness of membership in an organized body.

While this view finds general acceptance, there is some tendency to drift away from it, especially among stations connected with the larger institutions; to minimize organization and administration, to emphasize the individual and his freedom of action, and to make relatively little provision for centralization in the direction and management of the experiment station. The increase in graduate students and their assignment to specialists in the experiment station has perhaps had a tendency in the direction of magnifying the department in some cases, and diminishing the coherence and the organized character of the experiment station.

In years past the individual specialist, and particularly the subject-matter department, was looked upon as the logical unit in developing research, and accordingly given large responsibility and the freedom of the field or the specialty. There was much to be said for that view from an academic standpoint. The paramount importance of the individual and the encouragement of individual initiative is more essential than ever in the growth of agricultural research; but this is not incompatible with the idea of organization and administration in recognition of a centralized responsibility.

In the differentiation of function between research, college teaching, and extension, the administration of these separate functions is superimposed on that of the various departments. Certain persons are selected from within these departments because of their special qualifications and assigned to the experiment station staff, the assignment carrying with it certain responsibilities to the director in carrying out features of the research program. This is logical, for research programs very often overstep departmental boundaries and require the united or coordinated efforts of different specialists. A division of funds among departments or specialists does not meet the requirements at the present time, for it does not insure a considered station program, and it tends toward departmental exclusiveness rather than coordination of effort.

PURPOSE OF ORGANIZATION

The aim of science is the organization of knowledge, the growth of which is dependent on research; and the purpose of the experiment station is to carry on organized research for the advancement of agricultural knowledge. It will not suffice for this research to be fragmentary, desultory, and independent, but all evidence points to the fact that to fulfill its purpose it needs to be selected with reference to the objectives and often coordinated in its conduct, and furthermore that it should be of a type such as the advancement of agricultural knowledge and the clarifying of problems require at the present stage.

The organization of an experiment station at the present time needs therefore to be a fairly strong and active one. This applies to the station as an institution or definite branch of the college and to its relations to other parts of the college. Within itself it relates to the staff, as the mainspring of all its productive efforts, to the investigations upon individual problems and projects, and to the setting up of a general program of operations, properly balanced and knit together so as to make the approach a comprehensive one and reasonably complete. And, finally, organization applies to the broader relations of the station to similar institutions in the study of regional questions, with which it has much in common.

FUNCTION OF ADMINISTRATION

To preside over this organization and carry out the administrative functions has become a large and highly important activity, calling for special qualities and sympathies in relation to research on the one hand and to agricultural problems on the other. The interests of these often will center in the administrative office. Not only is it an important function—it is well-nigh indispensable to meeting the full mission of the experiment station under prevailing opportunities and conditions of support. The directorship is not only a job well worth while but one worthy of the highest qualifications and the most studious effort in promoting this most intellectual type of activity.

The director himself will rarely function as a specialist but rather as an organizer having a broad grasp and sympathies with agricultural science and practice, intimately acquainted with the general principles and essentials which pertain to all research. Upon his judgment will depend, in large measure, the selection and adaptation of a working staff. With the aid of the staff he will determine upon the principal lines of activity. Within

these he will exercise his authority to see that plans are properly made and properly considered. He will serve as a coordinator, a directive agency to see that the main purpose does not become lost in the maze of details, a sympathetic critic and counselor where impersonal judgment is needed. Naturally he will leave the details of execution to the specialists, but he will expect to know whether or not the projects are being adhered to and are going forward effectively. These functions he can discharge in a helpful way without limiting individual initiative and responsibility, or losing the confidence and support of his staff.

Such a view of the place of administration, and of the opportunity through it of so directing the activities of specialists to definite ends as to avoid becoming lost in particulars, was recently voiced by President Coolidge, and is applicable in this connection. Speaking in high appreciation of the value of such technical specialists, he remarked that "while they are wonderfully skilled in their own subject they often do not comprehend its relation to other subjects," and he added that "these talents will reach their greatest usefulness only when directed and coordinated by the wisdom of a comprehending executive who may not always know but who rarely fails to understand."

COOPERATION AND COORDINATION

The passage of the Purnell Act and the formulation of definite plans for a combined attack on problems of national importance gave unusual stimulation to cooperative enterprise. During the fiscal year 1927–28 about 900, or approximately 13.5 per cent, of the total number of station projects were carried on cooperatively between several stations or with the Department of Agriculture, this indicating an apparent gain of 50 per cent over the preceding year. All of the stations were involved, several carrying on over 35 cooperative projects each.

Many regional problems involving several stations are being attacked successfully on a cooperative basis. There are also the broader problems especially suited to national cooperative effort which are participated in by the Department of Agriculture and many stations. Of the 20 or more regional cooperative enterprises in progress, the work in corn improvement by 12 stations in the Corn Belt and Northwest and the studies on the development of oil sprays by several northern and northwestern stations have been especially outstanding.

A large proportion of the cooperative undertakings have involved the collaboration of the Department of Agriculture. With this collaboration, organization and follow-up have been generally more systematic than where the cooperation has been operative wholly between the stations. The department bureaus have often supplied the initiative or have helped to outline definitely and organize the projects from the start. The results of this type of enterprise seem to have emphasized some of the essentials of successful cooperation in research, pointing to the importance of a plan of operations and a considerable measure of coordination of the investigation under such plan.

Although the merits of cooperative endeavor have been set forth often, these may be briefly referred to in the light of continued experience. Cooperation in research assumes a problem in which various parties have a mutual interest and an understanding which permits each to contribute some part essential to the investigation. As a working arrangement it furnishes the combination of experience, viewpoint, and facilities which promote better organization and more systematic investigation. It economizes effort, avoids unnecessary duplication on an independent basis, and supplies replication where necessary, at the same time making the results of individual investigations comparable and supplementary, and thus providing for a more comprehensive attack on organized problems.

Opportunity often is afforded through cooperation for utilizing more effectively the special qualities and aptitudes of different workers. The working out of large, many-sided problems gives opportunity for a wide variety of aptitudes, involving experience, manual dexterity, and practical knowledge, as well as mental ability and imagination; and these often can be employed in collaborative enterprises to very great advantage, hastening the advance and greatly extending the reach expected from individuals working single-handed.

The unusual facilities available for setting up and carrying forward cooperation are in large measure responsible for the notable development of cooperative relationships and undertakings. The Joint Committee on

Projects and Correlation of Research in the Association of Land-Grant Colleges and Universities, concerned with the research relations among the stations and between the stations and the Department of Agriculture, has been influential in this field. The appointment of the research committees has provided an organization which can be used for developing a satisfactory system of cooperative investigation. The close contact between workers through meetings of scientific societies and conferences gives further opportunity for discussion of the aims and progress of research.

Regardless of the encouraging growth of cooperation, much remains to be done to strengthen the movement and to give the features more tangible form. In many cases the cooperation is rather loose and ineffective, lacks organization, and does not go far beyond mutual understanding; often it is quite informal, representing verbal agreements between individuals. Again, relatively few stations have taken up the national projects, especially in some of the newer lines. There has been a disposition to set up projects on independent and unrelated bases, while in other instances the cooperation is indefinite in its conformity to a working plan. Concerted and correlated effort on the national cooperative projects has not been as active as was anticipated. If the efforts at cooperation are to be worth while they will need to receive the active interest and support of administrative officers and not be left wholly to individual workers.

Cooperation and correlation imply a division of the field on large or complex problems. Many of the subjects needing more intensive and comprehensive study reach beyond the boundaries of separate departments or the purview of specialists in them. They involve a determination of what is embraced in them and provision for carrying forward the essential parts. Other subjects apply to such wide territory and diverse conditions that to understand them calls for concerted action on a coordinated plan.

Research involves both analysis and synthesis. The analysis comes first, in laying out the line of approach, to avoid the effort being fragmentary and one-sided and failing to take account of relationships of parts to one another and to the whole. Analysis is preparatory to a division of the field and coordination of effort which will keep the primary objective in view. There may be as much opportunity for initiative and independence of effort of participants in their respective lines as if there were no correlation, but if the common end toward which all are endeavoring to make a contribution is kept in view, the combined contribution may be increasingly larger and more significant.

The idea of cooperation and coordination is growing steadily. The cooperative spirit is more dominant and favorable. Even though the details have not been fully worked out, the outlook gives much encouragement. Even where it is not definitely organized its benefits may be realized in considerable measure through the laying out of station programs.

This requires special administrative attention, to view problems in their entirety and arrange for such complementary action as individual cases make necessary. Some of the newer subjects, like rural economics and home economics, give much opportunity for attention in the direction of supplementing their efforts and enlarging the attack through other departments. The subject will require continued encouragement and thoughtful study. Opportunity for this will be presented in connection with the proposal of new projects and in the periodical survey of the station program.

As the Joint Committee on Projects and Correlation of Research pointed out in its last report, a larger and more effective measure of cooperation and coordination is regarded as one of the greatest needs of agricultural research at the present time. This is not wholly a question of whether or not individuals and institutions shall actively cooperate; it is a matter of relating investigation so that it will give more comprehensive and effective study to leading subjects, avoiding unnecessary repetition and duplication and directing it in an orderly way toward the various features which must be considered before such subjects can be worked out. Such correlation, so far from being a question of subordination of individual initiative and independence, is a challenge to originality.

A COORDINATED RESEARCH PLAN

Elsewhere in this report an account is given of plans for the development of agricultural research and related efforts in the British Empire. These plans have been promulgated on an

extensive scale, with the provision of 1,000,000 pounds a year for their support, to be supplemented in many cases by local contributions equivalent to the imperial grants.

The dominating motive in this large enterprise is that of making the British Empire more self-sustaining in the matter of foodstuffs, and to that end the development of an imperial consciousness and unity of effort is sought. The plans were inaugurated somewhat more than two years ago, and were matured after extensive and thorough consideration of existing conditions in the Empire and its colonies, and of special needs for expansion in various directions.

It is interesting to note the emphasis placed on fundamental research designed to discover broad facts and principles, as contrasted with experiments and investigation dealing with local or more limited interests and aspects. The plans evidently contemplate a considerable measure of centralization to attain the desired ends, and look definitely to cooperation and coordination as means of making the various lines of effort as highly effective as possible.

This is one of the most important developments in agricultural research in recent years, and because of its plain and high purposes its progress will be followed with unusual interest.

INSULAR EXPERIMENT STATIONS

Under special provisions of the Congress, agricultural experiment stations are maintained by the United States Department of Agriculture in Alaska, Hawaii, Porto Rico, Guam, and the Virgin Islands. These stations have continued under the administrative supervision of the division of insular stations, Office of Experiment Stations.

All support for operating the stations is derived from appropriations made by Congress. The total incomes of the stations for the fiscal year ended June 30, 1928, were as follows: Alaska, $76,240; Hawaii, $54,940; Porto Rico, $56,460; Guam, $25,000; and Virgin Islands, $25,000. The proceeds from the sale of products, which were deposited in the Treasury as miscellaneous receipts and were not available for station maintenance, amounted to $6,894.04.

There was no change in the policies of the stations and in their activities except the suspension of some lines of work because of inadequate support for their development.

ALASKA STATIONS

On account of the wide differences in climatic conditions in different parts of Alaska, experiment stations are maintained at Sitka, Kodiak, Matanuska, and Fairbanks.

The principal investigations at the Sitka station, which is located in southeastern Alaska, a region with a heavy rainfall and rather constant temperature and rugged topography, are along horticultural lines. The work with small fruits and vegetables has yielded important results. Crossing the native wild strawberry and some cultivated varieties gave many thousands of seedlings, from which a number of hybrids of great promise have been selected. Plants of some of the hybrids have been distributed widely in the Territory, and they have proved hardy in regions where commercial varieties have winterkilled.

Potato seedlings also were produced, and from among them a number of promising varieties have been selected. An experiment with bulbs was concluded, and a circular describing the work was issued. Narcissus, tulip, gladiolus, and other bulbs were successfully propagated at the Sitka station, and it is believed probable that a limited industry in bulb growing could be developed.

The Fairbanks station is located about 6 miles from the town of Fairbanks in a region that is typical of large areas in the Tanana and Yukon Valleys. Grain growing and stock raising are important industries in these valleys, and the station is giving attention to them. Adaptation tests have been made of a large number of varieties of cereals and forage plants. Siberian No. 1 wheat, a selection from an unstable hybrid wheat received from a Siberian experiment station, and barley Hybrid No. 19, produced by the Alaska stations, are outstanding among the cereals grown in this region. Extensive trials have demonstrated the value of the variety of pea known as Alaska for forage, soil improvement, and seed. Siberian alfalfa has been found well adapted to the country. Some apparent hybrids are under observation.

At the Fairbanks station an experiment is in progress in crossing the Asiatic yak with Galloway cattle in an attempt to produce a hardy beef animal for interior Alaska. A number of the hybrids have been under observation for several years, and their ability to withstand the severe winter

climate with a very limited amount of feeding is assured.

The Matanuska station, located about 2 miles from that town on the Alaska Railroad, is in one of the most promising valleys of the Territory. Cereal growing, stock raising, and dairying all appear well adapted to this region. Adaptation studies occupy much of the time of the staff. An experiment in developing a hardy race of milk cows by crossing Holsteins and Galloways is in progress. A number of the crossbred animals gave in their first lactation period nearly as much milk as the average of the Holstein herd, and the butterfat content of the milk was increased appreciably. The ability of the crossbreds to withstand cold and storms is quite marked.

A small creamery, established cooperatively by the station and the Alaska Railroad, is proving a boon to the settlers of the Tanana and Matanuska Valleys. The railroad buys cream and ships it to the creamery, paying local prices of butter for the butterfat.

The work at the Kodiak station has been reduced to the maintenance of a small herd of purebred Galloway cattle and experiments on wintering them on a limited amount of locally produced forage. This region is representative of a large area in southwestern Alaska where summer pasture is abundant but where desirable methods of winter management of stock are little known.

The retirement of C. C. Georgeson on December 31, 1927, marked an important event in the history of the Alaska stations. For nearly 30 years he planned and directed their work, often pioneering under trying circumstances, and to him must be given much credit for demonstrating the agricultural possibilities of Alaska. Doctor Georgeson was well fitted by temperament, training, and experience for the work in Alaska, and he carried it on with a faith and enthusiasm which accounted in no small degree for the success of the undertakings.

The work of the Alaska stations under Doctor Georgeson has shown that there are agricultural possibilities in that Territory and that a more or less specialized agriculture is not only possible but may be quite profitable in many regions. The stations have been especially valuable in showing settlers what to avoid in their efforts to develop an agricultural industry.

On the broad base of the agriculture laid by Doctor Georgeson it is now possible for the stations to turn their efforts to some of the more concrete problems that await solution. He was succeeded by H. W. Alberts.

HAWAII STATION

The station continued its efforts to diversify the agriculture of the Territory and to discover crops that might supplement the sugar and pineapple industries, which now constitute at least 95 per cent of the agricultural production of the islands. Especial attention was given during the year to the edible canna for starch production, coffee, and the Macadamia nut.

The agronomic features of edible-canna production have been well worked out, and its adaptability as a crop to a large area in Waimea, on the island of Hawaii, has been shown. This area is not suited to sugarcane or pineapple production, but yields of 40 to 42 tons per acre of canna roots, containing 24 per cent of starch, were found practicable. Some manufacturing difficulties are yet to be overcome. Unfortunately, the small mill that was built to extract the starch was closed on account of financial difficulties. Studies were continued on the physical properties of canna starch in an effort to develop new uses for it in case the starch industry should be revived. If the manufacturing problems could be solved successfully and a mill established on a sound basis, those who have grown the crop believe that a new industry could be developed for a large homestead area on the island of Hawaii, and for other regions of the Territory, without in any manner competing with the sugar and pineapple industries.

Another potential industry that has been fostered by the station is the growing of Macadamia nuts on a commercial scale. Problems connected with the propagation of the trees, selection for quality, and preparation for market have been given attention. Several thousand trees have been planted on the various islands, and some of the older trees are coming into bearing. Samples of the nuts submitted to confectioners and others have had a high value placed on them.

A study of the colloids in the volcanic soils of Hawaii has begun. As these areas are quite extensive, the solution of some of the problems relative to their behavior should be of great value to the future development of the agriculture of the islands.

A large amount of attention is paid to the introduction of tropical varie-

ties of fruits and vegetables, their further improvement by breeding experiments, and studies of their propagation and uses. Extensive collections are maintained, and much valuable material has been distributed for wider testing. Many varieties of mangoes, avocados, bananas, breadfruit, and other fruits, introduced by the station, are now being grown extensively. Vegetables of oriental origin have been studied and their uses and food values determined. A yellow variety of corn that will grow near sea level has been produced, and progress has been made toward the fixing of a heading type of lettuce that can be grown throughout the year at low elevations.

Under special authority of Congress, the station carried on extension work for a number of years. Extension agents were maintained on the islands of Hawaii and Maui to assist farmers with their problems, and the value of their services is quite generally recognized. On Maui a small demonstration farm is operated by the extension agent, who devotes considerable time to experiments on the adaptation of crops to the elevation at which the station is situated. This tract is representative of a considerable area of homestead lands, and as an immediate result of the work, a planting was made of nearly 100 acres of pineapples at an elevation previously thought too high for the profitable growing of this crop.

Boys' and girls' clubs have been established on nearly all the larger islands, and during the past year more than 1,200 boys and girls were enrolled in 4-H standard clubs. Several new communities were reached during the year.

PORTO RICO STATION

The Porto Rico station is devoting most of its efforts to investigations of problems relating to established agricultural industries and the development of others that appear promising.

The maintenance of a laboratory at San Juan for the study of some of the problems pertaining to the citrus and pineapple industries is necessary as the main station at Mayaguez is remote from the regions of the commercial production of these crops. Special attention is given to the use of fertilizers, suitable soils, and proper time of harvesting, and the development of methods of packing and shipping so that the fruit will arrive in New York in a condition to bring maximum prices. A study has been begun to ascertain the cause of a root disease of citrus trees that is causing considerable apprehension. A large grower has placed a portion of his plantation at the disposal of the station for investigations of this trouble. Citrus scab has received attention, and an effort has been made to produce a good commercial grapefruit that will be more resistant to scab than those now grown. Second-generation hybrids are being grown to test their resistance to scab.

Much attention has been given to coffee investigations in the hope that the plantations which occupy a considerable portion of the central part of the islands will be made more profitable. Extensive experiments have shown that on many soils the use of complete fertilizers is desirable, but if the cost of fertilizer is too great in proportion to the price of coffee, phosphorus may be omitted from applications to certain soils. Nitrogen and potassium are needed quite generally. Experiments on topping coffee trees have shown that while topping considerably facilitates the gathering of the crop and contributes to a uniform appearance of the plantation, the gain is made at the expense of yield. In one experiment, covering a period of 10 years, the yield from trees topped uniformly to 6 feet was one-third less than from untopped trees of the same age.

The station is giving attention to plant breeding, especially with sugarcane and corn. The sugar industry of Porto Rico was threatened because the leading varieties of cane grown were especially subject to mosaic, but disaster was averted through the introduction of Uba and other resistant cane varieties. From many thousands of seedlings produced by the station, several promising resistant strains or varieties have been selected, but their commercial value remains to be demonstrated. All these were from open pollinated tassels. A successful technic has been worked out for crossing varieties with known characters, and there are now on hand a number of second and third generation hybrids of known parentage, some of which are considered quite promising. They are resistant to mosaic, have good field characters, and the juice appears to be high in sucrose and purity.

In the Tropics dependence is usually placed on field corn for table use as the common varieties of sweet corn do

not flourish. A strain of corn developed by the station has shown such improved quality in selfed lines as to suggest the possibility of producing a strain of sweet corn adapted to the Tropics without recourse to crossing with field corn.

The occurrence of coconut bud rot in Porto Rico was shown by the station, which supervised a campaign for its eradication. During the study of this disease it was found that the common hat palm of Porto Rico was subject to attack by the same organism.

GUAM STATION

The Guam station continued to cooperate with the insular government, especially with the schools, in various enterprises looking to the development of the agriculture of the island. Materials were supplied and the plantings of forage plants at the Government farm were supervised in an effort to test the adaptability of various plants to Guam conditions, as well as to supply forage for livestock belonging to the island government.

The coconut-scale situation in the island appears to be well in hand, as an equilibrium seems to have been established between the scale and its parasitic and predacious enemies. A small black beetle, *Cryptogonus orbiculus nigripennis*, found locally and bred extensively, is responsible for much of the scale destruction. An attempt was made to send some of these insects to Fiji, which is suffering from coconut-scale depredations. The European corn borer is present in Guam, and through the cooperation of the Bureau of Entomology of the Department of Agriculture, parasites have been introduced, nearly 2,000 being liberated from breeding cages during the year. In Guam two crops of corn are produced annually, and it has been observed that the crop that grows regularly and vigorously is less injured by the corn borer than is the crop that is stunted by drought. Parasites have been introduced from Hawaii to combat the sugarcane borer. Some evidence has been secured that indicates the cane borer will attack coconut trees through young growing tissues.

Improvement of native livestock by the introduction of purebred sires and feeding experiments to determine the value of locally produced feeds as substitutes for those imported from San Francisco are in progress. Coconut meal, a local product derived in the extraction of coconut oil, is cheap and fairly abundant, and its value as an important constituent of the rations of milk cows and swine has been established. It can safely and profitably constitute up to 50 per cent of the concentrated feed given. Considerable attention has been given to poultry, especially their breeding, feeding, and diseases. The prevalence of internal parasites makes the raising of chickens a precarious industry. Extensive experiments with anthelmintics in progress may develop a successful method of treatment.

Adaptation tests of grasses and leguminous plants for forage are in progress in cooperation with the Office of Forage Crop Investigations of the Department of Agriculture. Para grass, elephant grass, *Paspalum dilatatum*, and other grasses have been introduced and found well adapted to Guam conditions, and they are replacing native grasses in pastures as rapidly as planting material is available. Introduced varieties of sweet potatoes, yams, yautias, etc., have been found superior to native ones, and their cultivation is being extended.

In the gardens and orchards, many varieties of tropical vegetables and fruits are being tested, and some of the introduced varieties have shown their superiority over the native varieties. Studies are in progress on methods for propagating some of the native fruits, excellent varieties of which are in danger of extinction. The station has continued to distribute large quantities of seed and planting material of improved varieties, the native cultivation of which is rapidly increasing.

VIRGIN ISLANDS STATION

The station in the Virgin Islands has extended its work to St. Thomas and St. John in addition to that which is carried on at St. Croix.

The station is attempting to improve the native cattle by the introduction of purebred sires. A nucleus of an improved dairy herd has been obtained, and a small purebred Guernsey herd is maintained to compare it with a herd of grade animals. Efforts are being made to improve the beef cattle and work oxen, for which there is a good demand. Considerable work with poultry has been undertaken, and one year's records show the superiority of Single Comb White Leghorns over the so-called native stock for egg production, although they show less vigor and have a higher mortality than the native fowls.

Efforts are being made to aid the sugar industry of St. Croix by the introduction of new varieties of sugarcane and by growing seedlings from standard varieties. In all, about 70 varieties have been introduced from other cane-growing countries, and more than 4,500 seedlings have been grown and tested. To insure against the possible introduction of insects and diseases, the varieties from other countries are first propagated on St. Thomas, where sugarcane is not grown commercially. When freedom from pests is assured the cane is brought to the St. Croix station for trial.

Many of the seedlings have been discarded after the first season's growth, but more than a thousand are still under observation, some of which are exceedingly promising. Of the introduced varieties that have been carried through several ratoon crops, some of the P. O. J. varieties from Java and several varieties from Barbados have considerably exceeded the common Ribbon cane in yield of sugar. The SC 12/4, developed by the station, and SC 22/31, also produced at the station, have been among the highest yielding of 35 varieties tested through five crops.

A beginning has been made in the establishment of a grass garden, and about 40 species of grasses and a number of other forage plants are being tested to determine their value under local conditions.

For several years the station has been conducting experiments on the production of vegetables for shipment during the winter to New York. The promising results of preliminary trials led during the past year to a cooperative experiment with the municipality of St. Croix, and 8.25 acres were planted to tomatoes, eggplants, peppers, and Bermuda onions. Unfavorable and expensive cultural conditions, delay in planting caused by heavy rains, the failure of the eggplants and the very light crop of peppers, and the arrival of the vegetables at New York when the market was well supplied by shipments from Cuba, Bahamas, and Mexico, all combined to make the enterprise unprofitable. It is hoped that with the experience gained a better showing can be made in the repetition of the experiment. If the production of winter vegetables can be made profitable, an important industry could be developed that would be of advantage to many.

Demonstration and extension work on St. Thomas and St. John for only one year resulted in a larger production of vegetables for home consumption. Much pioneer work had to be done to arouse the people and secure their interest in this work. Cooperation was maintained with the department of education in its school work. A municipal nursery was established in St. Thomas, through funds provided locally, and under the station's guidance a large number of seedlings of many kinds were raised and distributed for planting in gardens and elsewhere.

WALTER H. EVANS.

SOME RECENT RESULTS

Examples of the results of recent investigations at the experiment stations, which provide information of general interest and application, have been brought out in the following reviews prepared by members of the staff of the Office of Experiment Stations. Although complete summaries of all of the important work in progress at each station have not been attempted, the reviews will serve to show that the stations are making definite efforts to solve a wide range of significant agricultural problems and are meeting with marked success in many diverse fields. These are evidences of the practical value of their work and the aid they are rendering in making the agricultural industry more resourceful and efficient.

SOILS AND FERTILIZERS

The yearly output of experiment-station work on the foundation subjects of the soil itself and of the upkeep or renewal of its crop-yielding power is of such extent that even the main topics here noted—still more the individual results cited—must be looked upon as examples only, suggesting rather than representing the far wider range of problems dealt with and useful knowledge brought to light. Progress appears at practically all points. Some new viewpoints have been established and certain older questions have been brought to the definite answer of experimental fact.

Aluminum toxicity.—The apparent toxicity to plants of aluminum in true solution has been shown by the Rhode Island station to be actual aluminum poisoning, not primarily an acidity injury. Aluminum in the form of the citrate, found to be soluble even at relatively high pH values, was toxic in solutions too low in acidity to permit of acidity injury. Further, col-

loidal aluminum compounds at very low acidities exhibited toxicity when in contact with barley roots. Soluble phosphates chemically equivalent to the aluminum present eliminated the toxic effect; and in concentrations of from 3 to 13 parts per million aluminum stimulated rather than depressed the growth of the plants.

Aluminum toxicity in soils, however, is likely to become a factor only when the soil pH value fails below 4.7, according to the New Jersey station, inorganic anions in the soil tending to prevent the presence of aluminum in true solution at higher pH values. The degree of acidity necessary for the true solution of aluminum was found to vary with the various acid radicals; the nitrate ion alone, however, permitted the formation of soluble aluminum compounds at nearly pH 6, whereas the presence of the sulphate ion tended to suppress the conversion of aluminum sols and gels into true solutions of aluminum salts. Mineral fertilizers tended to coagulate the colloidal iron and aluminum compounds in the soil. Treatments either of artificially prepared zeolites or of actual soils with solutions of aluminum and of ferric salts were shown by the Arizona station to be capable of destroying base-exchange capacity; a capacity probably important in plant nutrition.

Soil acidity and lime requirement.—In a large number of soil types of a considerable range in pH value the Delaware station observed that the buffer capacity of a soil must be considered in making recommendations for acidity correction applications. Lime-requirement determinations as heretofore carried out were shown to be inaccurate in so far as the determination of the "acidity correction" value of lime applications upon soil is concerned. Power to resist change in pH value when alkaline or acidic substances were added to the soil varied from a minimum value of 0.44 to a maximum of 7.6. In terms of practical effect, the application of a given quantity of burnt lime for acidity correction, or of sulphur to control potato scab, might produce upon the least buffered of these soils a reaction unfavorable for crop growth, whereas upon the reaction of a highly buffered soil it would have little effect.

Acids which have been adsorbed, i. e., are chemically adherent upon the very large aggregate surfaces of masses of minute particles, were indicated by the Michigan station as a cause of the buffer action of acid soils; and at the Delaware station the buffer action in soils was shown not to depend, as had been supposed, mainly upon the soil colloids as such. The progressive removal of the electrolytes from a soil colloid caused a concomitant decrease in buffer action until the finally purified organic colloid had practically no buffer capacity.

Of more or less immediate practical significance are the effects of certain nitrogenous fertilizers, all of which, according to the Alabama station, have some effect upon the soil pH value. Sodium nitrate, calcium nitrate, and cyanamide raised this figure, (decreased the acidity), whereas ammonium sulphate, ammonium phosphate, Leunasalpeter, ammonium nitrate, and urea, in order of diminishing effect, lowered the soil pH value (increased the acidity). Acidification by nitrogenous fertilizers could be avoided by supplying 75 per cent of the fertilizer nitrogen as sodium nitrate and 25 per cent as ammonium sulphate. This combination left the soil reaction unchanged. The acidity developed by ammonium sulphate could be corrected by supplying with each pound 2.2 pounds of basic slag. The use of basic slag as a source of phosphorus to prevent acidification by acid-forming sources of nitrogen is believed to be practical therefore.

Alkali soils.—Sulphur treatment and leaching made the calcium more reactive, causing it to replace the sodium contained in the exchange complex in alkali soils at the Oregon station; and the products of biological agents, also, acting upon the calcium carbonate of the soil, were found by the California station gradually to bring about a further replacement of sodium by calcium.

The Washington station showed that alkali soil may originate from irrigation waters containing soluble salts; and at the Arizona station, cooperating with the United States Department of Agriculture, it has further been shown that crop plants appear to absorb water selectively from saline irrigation waters and to be unable to obtain the water needed for normal growth from a solution containing more than from 1.5 to 2 per cent of salts. To prevent excessive accumulation in the root zone of alkali salts from saline irrigation water, therefore, such water would require to be provided in quantity sufficient to offset as nearly as possible the selective absorption of water by the plants.

The permeability of alkali soils was increased at the Oregon station by alternate wetting and drying.

Soil organic matter and nitrogen.—Observations covering a considerable range of mean annual temperature and humidity conditions agreed substantially with the result of a fundamental mathematical analysis contributed from the Missouri station in showing that the average nitrogen content of ordinary soils increases two to three times with every 10° C. of fall in the mean annual temperature. It would seem possible, according to this result, to build up the nitrogen content of the soil in the North because the low annual temperature would favor its preservation. In the South, however, it would appear difficult to increase the nitrogen content permanently by green manuring because the high temperature militates against nitrogen accumulation.

The supplying to the soil of organic matter in a suitable form, together with more or less nitrogen, by the composting of straw and like wastes with the addition of certain of the common fertilizer ingredients to hasten the production of a properly decomposed artificial manure, while in itself merely the natural outgrowth of a very ancient practice, has none the less been made the subject of useful investigations with regard to details of method, the practicability of this type of composting, and the actual value of the product.

The New York State station has observed an acceleration of the decomposition of straw by the addition of a mixture of ammonium sulphate, superphosphate, potassium chloride, and ground limestone. The Oregon station found from 0.5 to 0.75 per cent of nitrogen in the form of ammonium sulphate, together with lime enough to prevent the compost from becoming acid during the rotting down, to suffice for the production of a good artificial manure under outdoor conditions; and the addition to the straw through the thresher of a mixture of ammonium sulphate, 10-mesh limestone, and superphosphate, led to the production at the Missouri station of an artificial manure which appears to have been superior, in its effect upon a sweetclover crop, to farmyard manure. The Missouri station considered the practice likely to prove economically successful under ordinary farming conditions.

The desirability of providing for the decomposition of such organic matter as straw, dry leaves, and the like prior to its incorporation into the soil has been reemphasized by such work as that of the New Jersey stations, where it has again been shown that nonleguminous crops may be handicapped seriously in germination and growth immediately following heavy applications of the dry organic materials by reason of the temporary tying up of nitrogen in the decomposition of the nonnitrogenous vegetable material.

At the Rhode Island station, nitrogen accumulations from green manures were apparently in close correlation with the percentage of nitrogen in the crops turned under; and the soil nitrate optima for three different groups of crops were indicated by experiments of the Rhode Island station as varying from 10 to 20 parts per million.

Inorganic fertilizers and special nutrients.—The crop-producing powers of limited quantities of phosphate, nitrate, and sulphate, and of potassium, calcium, and magnesium have been studied at the Oregon station. The yields rose with increases in the phosphate concentration up to 128 parts per million; 64 parts per million of nitrate was found insufficient for the proper formation and maturity of seed; and sulphate up to 15 parts per million had a decided beneficial effect upon alfalfa. Beyond 15 parts per million, sulphate showed a slight tendency to decrease the yield.

Additions of calcium beyond a concentration of 32 parts per million did not benefit growth to any extent although more of calcium was required to bring about the first substantial increase in growth than of any of the other nutrients. In the potassium experiments the yield continued to increase up to 44 parts of potassium per million. Leaves yellowed, wilted, and dropped, in the complete absence of magnesium. These effects were still slightly noticeable in the presence of 2 parts per million of magnesium, and increases in yield continued up to 128 parts per million.

Such growth of corn at 0.1 part per million of phosphate as to indicate that maximum growth could be had if that concentration could be maintained throughout the growing period was obtained by the Alabama station, however. Corn and soybeans appeared capable of maximum growth in maintained potassium concentrations of 2 parts per million, possibly less.

The soil reaction and certain bases have been found by the California station to affect the solubility of phos-

phates in the soil. Iron phosphate was found least soluble at pH 3. The iron was precipitated with the liberation of phosphate at less acid reactions. The phosphates of aluminum and of manganese showed themselves least soluble at a slightly acid reaction. The solubility of calcium phosphate was depressed mainly by dissolved calcium compounds, secondarily by excess calcium in alkaline solution. Alkalinity alone appeared to produce basic phosphate with the liberation of some phosphate in solution.

Iron was shown by the Michigan station to be much more active than aluminum in the insolubilization of phosphates; and dicalcium phosphate appeared at pH 5.6 or a little higher. Neither soil reaction nor the iron and aluminum content were thought to account for the very low solubility of the phosphates in the soil.

Phosphate behavior in highly acid muck soils has been reported upon from the same station, one of the main findings having been an absorption of water from highly concentrated monophosphate solutions, such that the phosphate concentration of the solution was greater after its contact with the soil than before; apparently, a negative phosphorus fixation. This effect was not noted with mucks of a relatively high pH value at any concentration of phosphate. The very acid mucks were able to fix phosphates after lime treatment, and mucks of high lime content lost a large part of their phosphate-fixing capacity when treated with acid. Moreover, when mucks that showed an indication of negative fixation were treated with as much water as they could render "unfree" the phosphorus fixation results were positive, regardless of the concentration of the phosphorus solution with which they were treated. The possible explanation of the frequent occurrence of phosphate deficiency as the limiting factor in muck and peat soils suggested by these results is evident.

Phosphate availability as influenced by nitrogenous fertilizers has been taken up by the Wisconsin station. An increase in phosphate availability from the application of physiologically basic fertilizers was indicated, with a corresponding decrease under the influence of physiologically acidic fertilizers unless lime also was applied with the last-named class. Liming greatly increased the availability of the phosphate in all plats and corrected the effect of the acid-forming fertilizers.

Similar work on phosphatic and potassic fertilizers has been carried out by the Alabama station, with conclusions regarding phosphates substantially the same as those above noted. The physiologically basic fertilizers decreased the water-soluble potassium in the soil, but tended to conserve the potential supply, while the acid-forming sources of nitrogen increased the water-soluble potassium at the expense of the potentially available supply.

Potassium availability in soils of low potassium solubility was observed by the Massachusetts station to be almost directly proportional to the water supply, potassium in the fertilizer rendering the experimental crop, (millet), nearly indifferent to variations in the water supply. At the Wisconsin station most of the soils treated with manure had more soluble soil potassium and less total potassium than similar soils not manured, and the plants obtained considerably more of the soil potassium from the manured than from the unmanured soils. In the opinion of the Tennessee station lime conserves soluble added potassium in a form probably available to plants, but resistant to excessive loss through normal leaching processes.

The water-soluble calcium content of some soils was observed by the Oregon station to be lower than the good growth minimum for alfalfa; and treatment of the soil with ground limestone and sulphur served to increase the water-soluble calcium concentration. Ground limestone alone was found capable of raising the water-soluble calcium content of certain soils above the alfalfa minimum.

Greater leaching loss of calcium was noted when lime was added by the Tennessee station to the subsoil than when the surface soil was limed.

The calcium content of the soil solution was increased at the California station by sulphur treatment; and the calcium and sulphate ions were found to be taken up together especially well by alfalfa plants. The application of sulphur and sulphates produced also definite increases in other bases in the soil solution. Heavy sulphur applications increased soil acidity and tended to inhibit nitrification, but up to 100 pounds per acre sulphur increased growth and the soil nitrogen content in arid soils.

Except on black-alkali lands, black-gas sulphur was shown by the Oregon

station to become available practically at the same rate as did inoculated sulphur, although the inoculated sulphur yielded sulphates more rapidly during the first eight weeks than did the uninoculated. On alkali soils 2 tons of sulphur had a decided flocculating effect, rapid flocculation appearing with approach to neutrality.

The rate of oxidation of sulphur in the soil was found sufficient to supply after some 30 days the sulphur requirements of almost any crop, at the Kentucky station, regardless of the sulphur normally present in the soil and rainfall. Sulphur with tricalcium phosphate appeared of some effect in wheat-culture experiments of the Maryland station, but in the use of sulphur with soluble phosphate a decided toxicity, considered due to the production of a strong localized hyperacidity, was noted.

Limestone and dolomite mixed with nitrogenous concentrates in the proportion of 4 parts of the liming material to 1 of the concentrate, at the Tennessee station, have been observed to keep the concentrate in good condition without significant loss of ammonia. Dolomite was less reactive than ordinary imestone. Two parts of 1 commercial concentrate with 1 of ground limestone remained free from caking for some weeks in a greenhouse.

Of the auxiliary nutrients, essential in minute quantities, the Rhode Island station has again shown manganese to be a valuable application in chlorosis of certain crops. The better results were obtained where the manganese was supplied in the solution form. An apparent superiority of dolomitic over other limestones of lower magnesium content, which had led to the postulation of a magnesium deficiency, has been indicated by the North Carolina station as probably an evidence of a manganese deficiency, capable of correction by the dolomites and by certain local marl deposits.

Soil microbiology.—Some 26 probably new forms isolated by the Utah station and including Actinomyces, bacilli, and micrococci have been found to be nitrogen-fixing organisms. Certain of the dry-farm soils of Utah had been observed to have produced good crops for years practically without legumes or nitrogen-carrying manures and to have at present in the surface foot more nitrogen than have the adjoining uncropped soils. Most of these soils fixed nitrogen actively when held at favorable moisture content and temperature.

The Iowa station reports aeration of the cultures as having accelerated nitrogen fixation by soil microorganisms, and recommends soil treatments to maintain sufficient aeration.

The nitrogen content of plant material must be about 1.7 per cent to supply the requirements of the microorganisms active in the decomposition of the material during the first four weeks after incorporation into the soil, according to the New Jersey stations, where it was also found that if the nitrogen content of the material exceeds 1.7 per cent, available nitrogen will be set free even within the first four weeks. When less than the nitrogen requirement of the organisms causing the decomposition is provided by the plant nitrogen content, however, the organisms will take up nitrogen from other sources, rendering it for the time unavailable for plant growth.

Methods.—The choice, modification, or device of methods for the investigation of the groundwork of soil phenomena underlying all such problems must be the first element of structure in the building up of a means wherewith to meet any agricultural soil problem. Inadequate methods may fail to yield any conclusion. Methods insufficiently accurate may lead to false conclusions, and these, in turn, to practice valueless because it has not been founded upon fact. Station progress in so fundamental a subject may well be indicated in a few illustrative instances.

A new procedure developed and improved by the New York State station for the staining of bacteria in soil-suspension films now makes visible so much larger a proportion of the bacterial soil population than has previously been seen actually in the soil, "that until the work had been repeated, it was thought that the preparations must have been contaminated with bacteria from some outside source."

Nitrification tests by the Oregon station have shown that in extremely sandy soils low in organic matter and buffer capacity the same quantities and kinds of nitrogenous material as are used in the soil types more frequently met with did not yield consistent results. The suitability of ammonium sulphate for nitrification tests on normally productive soils was confirmed and suitable conditions for the test in the exceptional soils mentioned were worked out.

Mechanical analysis of soils by the taking of hydrometer readings of the

densities of their water suspensions at empirically determined intervals has been studied by the Michigan station, data having been published in support of the belief that the analysis of a soil in 15 minutes by this method is possible.

A form of stirring apparatus, also devised at the Michigan station for the dispersion of soils and based upon the soda fountain milk-shake stirrer, has been further applied by the Ohio station to the dispersion of soils in such a way as to shorten the work of determining lime requirement and the replaceable calcium content; and the belief is expressed that such dispersion should prove applicable to other chemical studies of soils. A partly chemical method for securing the dispersion of soils for mechanical analysis has been contributed from the Utah station.

A study of the measurement of some physical characteristics of soils, also at the Utah station, yielded a simple method for the determining of the shrinkage on drying simultaneously with the determination of the modulus of rupture and of cohesion, increasing the value of the determinations and decreasing the time and labor required for making them. An apparently rapid and accurate method for the verifying of the results of soil volume weights as determined by the soil tube has been devised at the California station. The new procedure consists essentially in comparing the dry weight of the soil removed from an auger hole with the natural volume of the sample as measured by filling the auger hole with heavy road or fuel oil, or heavy sirup of known specific gravity, the volume of liquid required being obtained from the weight used, determined by difference.

The accuracy of the quinhydrone electrode as an aid in the study of base exchange has been investigated at the Indiana station, with the result of establishing the possibilities and limitations of the procedure, so that apparently sufficient accuracy to warrant certain conclusions, in spite of the multiplication of experimental error during computations, can be secured. The necessity evidenced in this instance for determining limitations as well as possibilities of procedures too valuable to be discarded on account of their limitations is a good illustration of the importance of thorough methodology. Such illustrations could be multiplied.

The study of methods is probably, from a general viewpoint, the least conspicuous field in which the results of experiment-station research on soils and fertilizers are to be found. The necessary place of such work in the research program has been thoroughly recognized by the stations, however, and the aggregate accomplishment has been large.

Henry C. Waterman.

FIELD CROPS

Investigations with field crops, as manifested by the work reported and the projects in which the stations are engaged, have aimed increasingly in the direction of fundamental research. Agronomists are profiting to a greater extent than heretofore from the experience of chemists, plant physiologists, and geneticists and are using their technic, findings, and collaboration in attacking new problems or untouched aspects of older inquiries. Some of the current results in a few important lines of field-crops work are reviewed briefly.

Improved crop varieties.—New varieties recently brought forth either as the results of definite aims in plant breeding or as by-products of investigation have been variously characterized by productiveness, earliness, disease resistance, adaptation to certain environmental conditions, or commercial value. Among these is Denton wheat, a pure-line selection from Mediterranean by the Texas station, which has proved superior in yield, rust resistance, strength of straw, and baking quality to varieties commonly grown in north Texas. Nabob, a pure line selected by the Ohio station from Nigger wheat, has been 50 per cent less susceptible to stinking smut than Nigger and slightly excelled it in milling and baking value, is very winter hardy, and has outyielded Nigger, Trumbull, and Fulhio. Ceres, a rust-resistant spring wheat obtained by the North Dakota station from a cross between Marquis and Kota wheat, has yielded well in the State, particularly where rust is a factor, and resembles Marquis in milling and baking quality.

Iogold oats, a pure line selected from Kherson by the Iowa station in cooperation with the United States Department of Agriculture has stiff straw, is resistant to stem rust, and has outyielded other prominent station selections and local varieties. Nortex oats, selected from Red Rustproof by the Texas station, is several days earlier than ordinary Red Rustproof, escaping to some extent severe

stem-rust infection, and is a high yielder for either fall or spring planting. Another selection of this station, Frazier oats, which resembles Fulghum in plant type and maturity although more productive, has given excellent yields when spring sown. Patterson oats, selected by the Pennsylvania station from Japan oats, is medium early and led in cooperative tests. Anthony, a high-yielding white midseason oats derived at the Minnesota station from a cross between White Russian and Victory oats, is highly resistant to stem rust.

Atlas barley, developed from Coast barley by the California station cooperating with the United States Department of Agriculture, is an improvement in yield, earliness, plumpness of kernels, and resistance to lodging. Vaughn barley, bred up in similar cooperation from a cross between Club Mariout and Lion barleys, has been outstanding in yields, is early maturing, and has shown a high degree of resistance to Rhyncosporium and the Helminthosporium diseases. Glabron, a smooth-awn barley brought forth in like cooperation from a cross between Smooth Awn and Manchuria barleys at the Minnesota station, resembles Velvet barley, although it has stronger straw and yields better. Peatland, a rough-awn variety selected at this station from Switzerland barley, is especially well adapted to peat soils.

Westex, a new cotton selected by the Texas station, is very early, has a short-growing season, and is better adapted to regions north and west of the present cotton zone. Pedigreed strains of Mexican Big Boll, being improved by the North Carolina station, have been outstanding in acre value and in spinning tests. Redwing, a flax selection of the Minnesota station, has outyielded other good varieties, matures early, and is rust resistant. The North Dakota station has brought forward Bison, a wilt-resistant flax with large seed, sturdy roots, tall straw, which surpasses the old standard N. D. 114 in acre yields and percentage of oil.

Two other contributions by the Texas station include Texas Blackhull, a high-yielding kafir, and the Macspan peanut, which matures earlier, yields better, is more uniform, and seems to contain more oil than does the ordinary Spanish peanuts. Geneva and York, new kidney beans derived at the New York State station from a cross between white and red kidney beans, surpass the commonly grown Wells in yield and quality and escape bacterial blight.

Quality in wheat.—The changes in the milling and baking industries in recent years concurrent with the growth of commercial baking and the decline of home baking have emphasized the quality factor in wheat and are largely responsible for an extensive and promising line of investigation. While the standards have stressed various physical qualities, during the last decade the protein content of wheat has become increasingly important because it serves as an index of bread-making quality. In fact, the Nebraska station has concluded that protein content shows a higher correlation with baking quality than does any other known chemical or physical factor or group of factors, and Nebraska millers consider protein content the best evidence of baking quality of wheat at time of purchase.

Research on the general problem has covered a rather wide range of inquiry, involving variety, breeding, environment, culture, harvesting and storage, and milling and baking. The North Dakota station observed that the protein content of seed wheat does not appear to influence the protein content of the resulting crop. In regard to seasonal influence, rise in temperature was found to result in an increase in protein and decrease in test weight, whereas an increase of moisture evidently depressed the protein content. The critical period for wheat appeared to be the two or three weeks just before harvest. Soil fertility, crop rotation and sequence, and tillage all appeared to affect the test weight and protein content. Many of these factors also affected diastatic activity of the flour, which seems to vary inversely with the protein content.

With reference to the effect of fertilizers, the Kansas station found that, in general, nitrogenous fertilizers, excepting manure or cowpeas for green manure, slightly increased the protein content of wheat. At the Arizona station wheat receiving nitrogenous fertilizers averaged 2.2 per cent more protein than wheat receiving no nitrogen in the fertilizer. The peculiarities of loaf volume and percentage of protein of the different wheats studied by the California station corresponded rather generally with the varietal characteristics in response to applications of nitrogen at various growth

stages. The flour strength in a variety seemed to be related to the protein content of the grain and to some factor or process connected with the developmental period of the plants which is reflected in ripening differences.

Durum wheats averaged distinctly higher in test weight than bread wheats, and resembled hard spring or bread wheat types in protein content when grown under similar conditions by the North Dakota station. The Illinois station observed that wheat grown upon black clay loam soil contained considerably more protein and gave a stronger flour than that grown on grayish-brown silt loam.

High wheat yields were found by the Nebraska station to be associated with relatively high-protein content and baking quality. In general, baking quality seemed to be determined more by soil conditions as influenced by climate and weather and by cultural practices than by inherent varietal characteristics. The extent to which wheat quality depends on the time and methods of harvesting, weather during harvest, and the care given the wheat thereafter was demonstrated by the North Dakota station. Wheat harvested when immature had a lower test weight than that cut in a more mature stage, whereas the protein content of wheat at different stages of maturity for different seasons did not vary consistently, probably because of variation in prevailing climatic conditions during the maturing period. As shown by baking tests, flour from the mature wheats was slightly better in quality.

Wheat standing uncut after ripening, exposed to summer showers, was found by the Utah station to increase in volume in kernel. High density was associated with high protein content, and wheat with low density and low protein content increased more in volume after being wet than wheat higher in protein and density. However, deterioration resulting from such exposure was not observed in chemical studies or in milling and baking tests.

Wheat weathered during winter in the shock by the Montana station was lowered in grade and impaired in germination and color, although the protein content remained practically constant after the initial reduction in the first two months of exposure. With wheat frosted at different maturity stages, this station found that the severity of damage depends upon the moisture content of the wheat kernels at the time of frost and the severity and duration of such frost, from 29° to 27° F., being low enough to cause frost damage in immature wheat. Wheat frosted when containing from 44 to 46 per cent or less of moisture, i. e., when in the stiff-dough stage, could produce as good bread as normal wheat harvested at the same time.

Fertilizers for small grains. — The plant-food needs of the cereals have provided a fruitful field of inquiry at the stations since their organization. The varied reactions of different soil types to treatments, and the further fact that natural fertility varies between and within fields on the same soil type and is modified by seasonal conditions and previous cropping, have made it difficult to prescribe definite fertilizer combinations generally suitable for a certain crop. Recent investigation on this problem has been concerned with the nutrient needs of the crop, especially at different growth stages, quality as well as quantity production, effects on the soil, and economy in application.

The small grains were found by the South Carolina station to respond most to nitrogenous fertilizer, although increases came from phosphorus and potassium on the lighter soils. Benefits derived from the greater quantities of complete fertilizer seemed due largely to the additional nitrogen. The grains reacted favorably to readily available nitrogen applied early in the spring, especially to the heavier applications. Ordinary nitrogen sources were about similar in effect when applied in equivalent amounts at this time. The findings by the Georgia Coastal Plain station were in general harmony with those obtained in South Carolina.

In southern Mississippi the Mississippi station found that oats responded best to a complete fertilizer, and that January applications surpassed those made in following months. The different kinds and rates of fertilizers applied to oats did not seem to influence rust control during a severe attack. In fertilizer trials with rice the Texas station found that 100 pounds of ammonium sulphate per acre was the most profitable treatment. Additional ammonium sulphate did not increase yields proportionately, and other materials were relatively unprofitable.

When wheat grown under various fertilizer conditions at the Ohio station was fed to rats, the results indicated that acid phosphate alone or a complete fertilizer containing acid

phosphate, potassium chloride, and sodium nitrate seemed to produce wheat with the highest vitamin B content.

Fertilizers for corn.—While the length of season of a corn variety and soil fertility have been considered as important factors in maturity and yields, the Ohio station found that proper application of fertilizers may also result in significant increases in yield and hasten maturity. Fertilizers applied in the hill provided best for the crop needs early in the season and manure and broadcast application in the later growth stages, indicating the value of supplementing the hill applications with the manure and broadcast fertilizer. The Georgia station observed that corn receiving potassium chloride in the row returned better yields than when the salt was broadcasted. According to results of the Georgia Coastal Plain station, fertilizers should be applied to corn as a side dressing on good soils and at planting on the poorer lands. The Alabama station found that sodium nitrate was best applied to corn five or six weeks after planting and preferably in one application.

On representative soil types in the piedmont and coastal plain the South Carolina station found that the corn yield depended largely on the quantity of nitrogen applied, whereas superphosphate affected yields only slightly and only light sandy soils responded to potassium. The influence of the variety or strain was noted by the Illinois station, where two disease-resistant inbred strains of corn, as well as their hybrid, gave increased yields for potassium treatment, while both a disease-susceptible inbred and a cross involving it failed to respond to potassium. Susceptible strains made relatively poorer growth where rock phosphate was the sole phosphorus source than where soluble phosphate was supplied. Superiority of strains thriving under such a condition seemed due to the more effective utilization of a limited quantity of phosphorus rather than to a superior foraging ability for phosphorus.

Cotton plant investigations.—Early fruiting, rapid growth and development, and early maturity are indicated as important qualities to be sought in the successful production of cotton under boll-weevil conditions. Fruiting studies, a part of an elaborate program of the South Carolina station, showed that flowers blooming early in the season have much better prospects of developing into open bolls than those appearing later. Varieties producing much of their fruit early in the season bore few flowers late in the season, and vice versa. Plants from early plantings took longer to begin fruiting but produced more flowers early in the season. Closely spaced plants also fruited early.

The Texas station found a considerable variation in the fruiting habits of different varieties, those bearing the most flowers also giving the largest yields. Varietal differences were observed by the South Carolina station in the beginning and rapidity of fruiting and in shedding and time required for square and boll development. No relation was found to exist between square and boll periods. The square period was practically constant throughout the blooming season and not prolonged as was the boll period. The percentage of squares blooming, or which set bolls, appeared to be influenced quite largely by insect activity, especially cotton flea hopper, rather than by any physiological peculiarity of the cotton plant.

Phosphorus applications made by the South Carolina station seemed to result in early maturity of cotton, apparently by stimulation of early fruiting rather than by a hastening of boll development. Nitrogen did not stimulate greatly the production of early fruit in comparison with cotton on infertile soil. Potassium increased the number of flowers borne before midseason and slightly decreased the percentage of total yield at first picking. The North Carolina station found that increases in the phosphorus in the fertilizer made for earliness, in nitrogen caused little or no change, and in potassium delayed maturity.

Considering that the absence of serious boll-weevil damage to cotton bolls in their later development stage might be correlated with thickness and toughness of boll wall, the South Carolina station devised apparatus to measure the resistance of the boll wall to penetration. Toughness of boll wall increased until the bolls were about 21 days old and practically full sized, whereafter age of boll was not important. Toughness of wall also seemed to be influenced by conditions during development, extremes of soil fertility, and variety. Neither resistance to puncture, wall toughness, nor boll size were found to be closely correlated with the percentage of cotton loss from boll-weevil attack.

Dormancy in potatoes.—The dormant period in potatoes, i. e., the time after harvest in which the buds sprout very

slowly or not at all, is an interesting subject of inquiry. The practical shortening or breaking of dormancy will permit the use of the early or spring crop as seed for the later or fall crop in regions with long growing seasons, as in the Southern States and in California.

The dormant period was found by the California station to be shorter in the harvest stage nearest maturity, and the average number of stems was observed to increase with the maturity of the potatoes. The rate at which mature tubers sprouted increased rapidly with the length of storage before cutting and planting, whereas tubers harvested when immature emerged from dormancy more slowly. Storage temperature and humidity also affected dormancy, tubers which had been stored at 22° C., (about 72° F.), under moist conditions sprouting very rapidly after cutting and planting.

The California station also found that the sprouting of mature White Rose tubers was hastened after treatment with ethylene for 6 days, while Idaho Rural potatoes were stimulated most after 15 days' treatment. Ethylene chlorohydrin was very effective for treating these varieties, especially White Rose, at 14 and 21 day periods after harvest. Ethylene dichloride was also effective, particularly with Irish Cobbler potatoes, either as a gas on whole tubers or in solution for cut sets. Treatment of small, mature tubers planted whole was much less effective than similar treatment upon large tubers cut before planting.

The dormant period of freshly-dug potatoes was successfully broken at the Arkansas station by treatment with ethylene chlorohydrin, or diluted lime-sulphur, or by storage for four weeks at the ordinary temperature prevailing at harvest. The storage method appeared the more practical for Arkansas conditions. Fertilizers high in nitrogen, and also peeling and cutting the seed before planting, likewise has some effect in hastening germination.

Another aspect of this problem was observed in Ohio where potato planting covers several weeks. The Ohio station found that each set in late plantings produced more sprouts than in early plantings. After the resting stage, until December or January in late varieties, potatoes were observed to send up only one sprout from each set until April or May, when a 2-sprout stage appeared. This in turn was followed about a month later by a 3-sprout stage and a continued increase in the number of sprouts as planting was delayed. The cycle was later in immature seed, due to their longer dormancy, and was also found to be retarded by storage near 32° F., single sprouting continuing for two weeks or longer after that of tubers stored at 38°.

Crop production affected by soil temperature.—The temperature of the soil markedly affects the growth and development of certain crops. The Florida station found an optimum soil temperature for the germination of cotton to be about 33.5° C., (92.3° F.), with no germination at 40° or at 14° or below, while between 15° and 35° the germination rate agreed with the Van't Hoff rule. Temperature appeared to be a limiting factor only above 20° and below 35°, some other environmental factor limiting the growth of cotton seedlings between these temperatures.

Temperature was found by the Florida station to be the chief climatic factor influencing yields of potatoes, moisture being secondary and showing its chief effects in modifying soil temperature and in influencing Rhizoctonia infection. Soil moisture content controlled such infection below 20° C. (68° F.) and temperature above that point. Temperatures during tuber growth were highly and positively correlated with the average weight of tubers produced in the successive plantings, the highest yields being made where these were about 17°. A light straw mulch reduced soil temperatures from 3° to 5° at a depth of 8.9 centimeters, which was held responsible for increase in the size and decrease in the number of potatoes per hill, the net result being more marketable tubers.

With Yolo sorghum the California station found that the soil at a 3-inch depth was warmer during the day if under solid black paper for nearly nine weeks and under perforated paper for about seven weeks than if left bare, whereas fluctuating and reduced temperatures, respectively, prevailed later in the season. Covered soil was generally warmer than bare soil at night, although soil under perforated paper was warmer up to the eighth week and cooler or fluctuating thereafter. The sorghum with the solid and perforated paper exceeded that on bare soil by considerable percentages in total production per plant of dry matter, culm

height, and weight of grain. The higher temperature of the soil early in the season evidently stimulated growth and yield.

Legume inoculation.—Research delving into isolation, production, and activities of the root-nodule bacteria of legumes has been in progress at the stations since the discovery of the significance of the bacteria in legume production, and has accompanied the phenomenal increases in acreage of alfalfa, sweetclover, and soybeans, and the extended use of red clover and legumes of more local significance. In summarizing more than 10 years of endeavor, the Wisconsin station has pointed out that the most successful use of the legume and the root-nodule bacteria must be based on facts and that the importance of the problem warrants unlimited effort for its solution.

As a means of inoculating seed the soil-paste method, either with water or milk, gave the most consistent results with soybeans at the Iowa station, its efficiency appearing proportional to the soil adhering. Direct sunlight, storage, lime, superphosphate, and rates of drying did not affect greatly the efficiency of inoculation. Application of as much inoculating soil as would adhere to moistened soybean seed was found as effective at the Kentucky station as larger quantities of soil used otherwise. Deferring the planting of inoculated seed up to six days did not result in poorer nodule production.

The period between the emergence of seedlings and general nodulation was found by the Alabama station to be generally short in warm weather and long in cool weather. The Missouri station found that common soil amendments, e. g., crop residues, manure, and potassium or phosphates, did not significantly influence the degree of inoculation of soybeans on three acid soils, whereas limestone caused great increases in nodulation. Low soil-moisture contents resulted in reduced nodulation at the Wisconsin station, which also observed that fertilizers in quantities large enough to reduce germination also depressed inoculation.

Strains of nodule bacteria were found by the Wisconsin station to differ considerably in their ability to promote plant growth of different species in the group including peas, lentils, and vetch, although nodules formed readily on all three plants. The Washington station observed that differences in the inoculating power of strains of alfalfa nodule bacteria were pronounced and uniform regardless of soil type, and differences in nitrogen-fixing power were also demonstrated. Vetch species differed notably in the rapidity of nodulation under like conditions at the Alabama station. The Illinois, Iowa, and Oklahoma stations found that strains of the soybean nodule organism differed markedly in their relative efficiency to produce nodules on different varieties.

Wheat yields after oats, potatoes, and uninoculated soybeans differed little at the Illinois station, whereas wheat after inoculated soybeans produced several bushels more than was produced after uninoculated soybeans. The results indicated that the effect of soybean inoculation on the next crop will be limited largely by soil fertility, particularly as to available nitrogen and phosphorus.

Forage problems.—The current trend of investigation with forage crops, like that of other lines of inquiry, has been toward the more basic aspects of research, although the practical application of the results always remains the ultimate object. A study by the Wisconsin station on the relation of the organic food reserves to the growth of alfalfa and grasses is an outstanding example of this tendency. Alfalfa was greatly reduced in vigor and productivity, weed infestations increased, and both winter and summer mortality of alfalfa plants were more pronounced, by frequent and early removals of top growth. The slowing up of root and top growth of alfalfa plants and their ultimate death from cutting often and at immature stages appeared due primarily to the inability of the plants to elaborate enough organic food reserves through photosynthesis to provide for adequate translocation to and storage of such reserves in the roots for the future development of the roots and tops.

Cutting alfalfa early and often, in contrast with mature cuttings, lowered the percentage and quantity of dry matter, of total available carbohydrates, and of total nitrogen in the roots during the growing season, so that pronounced differences occurred at winter dormancy. The amount of winter injury was generally related to the frequency of removal of top growth and the quantity remaining uncut in fall and winter. Susceptibility to

winter injury was increased by low percentages of dry matter and low concentrations of reserves in the roots at winter dormancy.

In grasses, the situation was found to be somewhat different. After mowing, much of the basal leaves of many grasses remains and provides for the production and storage of enough reserve foods to sustain life of many plants, while similar cutting removes practically all the photosynthetic area of alfalfa, and the faster exhaustion of the stored foods often results in death. However, all the physical, chemical, and biological responses of timothy, bluegrass, and redtop, as well as those of alfalfa, indicated the importance of organic compounds resulting from photosynthesis as limiting factors of growth for all perennial forages. The principles brought forth in this study find many practical applications in the management of hay and pasture lands.

The problem of obtaining improved grasses and legumes suited to local conditions and special purposes receives much attention from the stations. The Florida and California stations have made important advances in finding forage plants suited to the varied conditions of those States. The Guam and Porto Rico stations have shown the adaptation and cultural and fertilizer needs of the larger forage grasses, including Guatemala grass, Napier grass, Merker grass, elephant grass, Guinea grass, Para grass, Uba cane, and Japanese cane in different situations in these islands. The North Dakota station has found that alfalfa is superior to perennial grasses in forage production on Fargo clay and that both alfalfa and sweetclover increase the total yields when included in forage mixtures. The Angleton grass introduced by the Texas station has been found to be valuable for pasture and hay on a wide range of soils and well adapted to the humid part of the Gulf coast plains of Texas.

Depleted, generally unproductive pastures responded strikingly to superphosphate, manure, and lime in experiments made by the New York Cornell station. On pastures grazed by yearling steers the Connecticut Storrs station found that without phosphorus gains could not be expected from other fertility treatments. In meadows on heavy clay loam the New Hampshire station obtained the greatest response from nitrogen without phosphorus or potassium, although phosphate treatments resulted in more clover than did nitrogen alone. The Wisconsin station found that sweetclover and other plants producing abundant spring growth made possible a deferred system of management for permanent bluegrass pastures. Heavy and close premature grazing throughout the growing season greatly reduced the productivity of bluegrass in comparison with light grazing.

Alternate grazing, close grazing, and heavy stocking successfully maintained mixed sod at the Washington station. The most promising improvement method tested, embracing top-dressings of manure and superphosphate, scarifying, and reseeding, continued to produce marked betterment in the grass yield.

Several of the Western States are solving their important range problems by carefully planned investigations. In range-improvement studies the California station found that the practice of deferred grazing on foothills generally gave good results, especially in the northern counties, where succession is much more rapid than in the drier south. Experiments carried on by the Colorado station showed that abandoned plowed areas in the foothills can be reclaimed by sowing such forage grasses as smooth brome, slender wheatgrass, and crested wheatgrass on a well-prepared seed bed. In many cases the grazing value of alkali seepage land might be improved by sowing suitable forage plants. Removal of sagebrush by burning was followed by increases of the natural grasses. It was indicated that areas undergoing revegetation should be protected from grazing for at least one year and the deferred-rotation system used after the first year when possible.

The Wyoming station found that high-altitude plants contain more nitrogen than low-altitude plants at the same growth stage and are characterized by a later start and more rapid growth. Shading prolonged the pasture stage. The forage plants studied generally made poorer hay when cut unduly late in the season, particularly the introduced grasses, such as timothy and redtop.

Weed control.—Recent weed investigations have necessitated a thorough knowledge of the life history and growth habits of the weed as well as of the infested crops. The California station found that the effectiveness of morning-glory or bindweed control de-

pends upon air and soil conditions which produce a water deficit, resulting in a subatmospheric pressure within the xylem system, and a period of exposure to the spray long enough for penetration of the toxic solution. Acids, bases, and hydrocarbons in commercial sprays used as herbicides rendered permeable the tissues from epidermis to xylem, while arsenic was most effective in killing tissue in the roots after translocation. The sprays used did not harm the infested crop.

Spraying experiments carried on by the Kansas station showed sodium-chlorate solutions to be the only effective treatment for bindweed control, the optimum time for the first spray being about the full-bloom stage. Sodium chlorate interfered with photosynthesis, compelling the use of the food reserve in the root until its exhaustion resulted in death of the plant. The Colorado station found that with proper cultivation bindweed could be controlled in two years, while the Washington station used clean cultivation, alfalfa, and heavy pasturing with hogs to advantage in control.

Puncture-vine seed in mature burs were quite effectively destroyed by a 50 per cent solution of oil emulsion at the California station, and the department of agriculture of that State found arsenic-trichloride spray effective in destroying the top growth of this weed. From its spray tests with sulphuric acid, the Arizona station recommended a 2 per cent acid spray for puncture vine, and also various solution strengths of this acid for controlling many other weeds.

When the New York Cornell station applied 178 pounds of sodium chlorate or 222.5 pounds of potassium chlorate per acre as dry salt late in the fall, Canada thistle was killed during the winter without injury to oats seeded on the plats the next spring. Chlorates seemed effective because of their rapid penetration through soil and slow decomposition, especially at low temperatures. The Ohio station found that Canada thistle could be controlled by suppressing the aerial shoots, thereby preventing seed production and accumulation of food reserves in the roots. The best eradication method for this weed comprised clean cultivation and the use of alfalfa or sweetclover as a smother crop.

Cooperating with the United States Department of Agriculture in rice experiments in the Sacramento Valley, the California station found that sprangle top and the earlier maturing types of water grass could be controlled by continuous submergence to a 6 to 8 inch depth, and late whitewater grass by pulling. The control of cattail required deep plowing and drying the roots in the spring, supplemented by pulling in July of the plants not killed by plowing. Thick stands of rice reduced the harmful effects of sedge, redstem, arrowhead, and waterplantain. A year or two of dry fallow usually controlled joint grass, and a thorough spring plowing suppressed spike rush if drying weather followed.

HENRY M. STEECE.

HORTICULTURE

Progress in horticultural research continued to be very satisfactory during the year. Perhaps the most impressive single feature was the important service rendered the fruit industry by the development of methods for removing arsenical residues from fruit and thereby permitting its sale in all markets of the world. Other fields of investigation, however, were not neglected, as was evidenced by substantial contributions of biochemistry, genetics, general breeding, and propagation to the science and practice of horticulture. Step by step new light is being cast on the fundamental causes of the various responses of plants to environment and to treatment.

Physiological studies.—The very material progress that has followed the application of physiological chemistry to the solution of horticultural problems is evidence of the value of fundamental investigation, even in such a practical field as horticulture. The investigations of Kraus and Kraybill with the tomato plant which led to the recognition of the need of a balanced nutritive condition within the plant in order to insure production was the steppingstone to much of the productive physiological research of recent years.

In some cases practices which had developed through empirical procedure of everyday use and which had been accepted as unquestionably correct have had to be modified in the light of the results of present-day studies. For example, it has been proved quite definitely that pruning fruit trees reduces top and root growth and lowers and retards production, and as a result of this finding pruning is now accepted largely as a necessary corrective measure for shaping the tree and for removing old exhausted wood.

The possibility of using the nitrogen content of the leaves as an index to the nutritive conditions within the tree itself was suggested by the California station as a result of studies with the pear. Apparently an abundance of nitrogen within the tree hindered the translocation of nitrogen from the leaves to the tree at the time of leaf fall. The studies indicated the possibility of controlling by defoliation the carbohydrate : nitrogen ratio and thereby influencing flower bud formation.

This hypothesis was also advanced at the Missouri station where defoliation of the tomato proved a means of modifying the carbohydrate : nitrogen ratio within the plant. Positive correlations were established at the New Hampshire station between the soluble and insoluble nitrogen contents of Baldwin apple fruit spurs and flower-bud formation, the samples being collected July 1 and August 1. Acid-hydrolyzable materials showed no relation to blossom-bud formation.

A remarkable adaptability in the pecan to existing conditions was observed at the Alabama station. Pecan buds that normally never would have opened developed into fruiting shoots when the normal buds were injured or removed. Finding that the pistillate flowers of the pecan were differentiated during a relatively short period in early spring suggested the importance of supplying adequate soil nutrition the preceding fall.

Repeated measurements at the Illinois station of peach fruits and pits during the growing period showed but little effect of thinning up to the time of the final enlargement, thus suggesting that the time during which peaches may be thinned may be materially extended. Fruit growth on the peach was periodical, first a stage of rapid enlargement, then a rest period, followed by the final enlargement of maturity.

Cyclical growth was observed at the California station in the development of lemon shoots. Three distinct bursts of growth were recorded and led to the development of the novel hypothesis that the successive cycles are due to the periodic activity of a specific growth-promoting substance which stimulates the growth process.

The inhibiting influence of reproduction upon vegetative growth, first noted at the Missouri station, was observed in studies with vinifera grapes at the California station. Here the fruiting and growth of the Muscat of Alexandria variety was greatly improved by the removal of part of the flower clusters before the flower buds had opened.

Fruit pollination.—Gradually but with certainty the pollination requirements and peculiarities of various fruits are being solved. Whereas a few years ago all failures to set fruit were attributed to external factors, such as unfavorable weather, lack of soil fertility, etc., it is now known that many varieties in practically all cultivated species are partly or wholly sterile when self-pollinated. In a few cases, notably in the sweet cherry, intersterility has been recorded.

The experiment stations have been contributing an important share to the world-wide studies of the pollination problem. During 1928 at least 10 of these stations, viz, those of Ohio, Maryland, Washington, California, New York Cornell, New York State, West Virginia, Delaware, Michigan, and Illinois, published results of pollination studies with fruits, and several more were engaged on the general problem. Some of the investigations went into the question of the underlying causes of sterility. For example, the Ohio station, working with the cherry, found that low pollen germination was apparently caused by abnormalities in the chromosome behavior which resulted in a low set of fruit. Abnormality in pollen development was noted in every cherry examined, most frequently in the Dukes, rather often in the sour varieties, and occasionally in the sweet varieties.

The Illinois station, working with the J. H. Hale peach, a variety well known for its failure to set when self-pollinated, found, as did the New Jersey stations, that low viability of the pollen was the immediate cause of sterility, but unlike the New Jersey stations, found some viable pollen and evidence of variability in the degree of sterility. The California station in studies with the vinifera grape observed that severe pruning decreased the viability of the pollen, an instance of the effect of external rather than genetic factors.

Plant breeding.—Plant improvement by means of breeding has been an important and productive field of station research. The Latham raspberry from the Minnesota station, the Cortland apple and the Sheridan grape from the New York State station, the Golden Jubilee and other peaches from the New Jersey stations, and the hardy fruits from the South Dakota station are among the practical evidences of

progress. Papers published on the manner of inheritance of various characters evidence scientific as well as practical progress.

With the knowledge that is now accruing from studies of chromosome behavior and the bearing of chromosome aberrations on hybridization, much more rapid advancement may be confidently expected in the immediate future. Compatibility or incompatibility of prospective parent varieties may now be forecasted and much futile work avoided.

Many of the stations are engaged in extensive fruit-breeding operations which have a dual purpose, the development of improved varieties and the formulation of principles of inheritance. The latter object is difficult of attainment because of the obscure and complex genetic composition of most cultivated fruits. Yet definite progress is being reported, especially in the direction of evaluating the potential breeding qualities of different varieties. Likewise information is being obtained on the inheritance of characters such as sex, vegetative vigor, resistance to various diseases, and qualities of the fruit.

Among contributions of the past year may be mentioned that of the Iowa station upon the value of selecting prepotent apple varieties as sources of vigorous rootstocks. Certain parents have been found to yield a large proportion of strong, vigorous seedlings. This evidence confirms the observations of the New York State and other stations that some varieties may contribute an unusually high proportion of valuable seedlings. The Illinois station has found that anthracnose resistance in the black raspberry is transmitted in a high degree by certain varieties.

Studies at the California station upon the inheritance of flower types in Cucumis and Citrullus led to the conclusion that perfect flowers are the primitive type from which the pistillate forms have arisen by dominant gene mutation. The flower type was remarkably constant in the muskmelon, watermelon, and cucumber. Of hundreds of watermelon and cucumber flowers examined, no instance was noted of perfect flowers on monoecious varieties. That the proportion of staminate to pistillate flowers in the cucumber is largely a genetic characteristic was indicated in studies at the Massachusetts station. However, modifications in the duration of light or the removal of pistillate blooms at anthesis affected the ratio and led to the hypothesis that sex is determined by some genetic-factor mechanism which controls the metabolism in the plant rather than by the actual sex expression.

Arsenical-residue problem.—Several of the stations, notably those of Oregon, Washington, Colorado, and New Jersey, have rendered highly effective service in helping to solve the arsenical-residue problem. The goal is not yet reached, but sufficient progress was made to allow the growers to market their apples and pears safely within the prescribed international tolerance of 0.01 of a grain of arsenic as arsenious trioxide per pound of fruit. The most successful method of treatment worked out by stations and the United States Department of Agriculture consists simply in spraying or washing the fruits with dilute hydrochloric acid, followed immediately by a similar treatment with clear water.

Many interesting side lights developed in the course of the investigations. At the Oregon station it was found that the natural wax forming on the surface of ripening fruits rendered cleaning difficult. This led to the recommendation for prompt harvesting and early treatment. Combined lead-arsenate and oil sprays were removed with difficulty, and the addition of spreaders not containing lime increased the task of removing the residues. Warming the acid solution to from 90° to 95° F. increased the effectiveness of the treatment. Apples with open cores could not be submerged to any considerable depth without serious injury, and since open cores were found in most varieties, the superiority of the spraying or sluicing method of treatment was established for the apple. The addition of lime to the rinse water proved beneficial in counteracting acidity.

Vegetable research.—There has been a very gratifying improvement, both qualitative and quantitative, in research with vegetable crops in recent years. Over one-fourth of the papers presented at the 1928 annual meeting of the American Society for Horticultural Science dealt directly with vegetables, many in a fundamental way.

Breeding both by hybridization and by pure-line selection has been productive of valuable results in vegetable culture. New tomatoes and cabbages from the Pennsylvania station, new spinach varieties from the Virginia

Truck station, sweet corn and tomatoes from the North Dakota station, and squashes from the Minnesota station have found definite places in the commercial industry. The California and Massachusetts stations have demonstrated the greater productivity of male than of female asparagus plants. The California station found that lettuce seed could be germinated in soils warmer than the optimum temperature by preexposure of the seeds on the surface of ice.

The Michigan station showed that the hardening of the tomato as a preplanting treatment is deleterious, since the hardened tissues did not resume normal development, the resulting plant being in effect a combination of a hardened and unhardened individual. The fruit of the hardened portion was inferior in shape and size. Hardened tomato plants showed a higher percentage of colloidally held water than did unhardened plants, but there was little or no difference in the killing temperatures.

Because of the importance of vegetables as food and because of their relatively short life history, it is certain that profitable research with vegetable crops will develop rapidly in the near future and may be expected to take into account the effect of coordinations of growth on the nutritive properties of such products as well as on their other qualities.

Experimental methods.—Coincident with general progress in horticultural research there has been a consistent improvement in the planning and conduct of investigations. Records taken by the California station in a citrus orchard prior to the actual beginning of the differential fertilizer treatments have shown significant differences between plats and between individual trees, despite unusual care exerted in the selection of a uniform site and in the laying out of the experimental areas. These data taken over a10-year period support the results obtained some years ago by the New York State station on a similar project with grapes and emphasize the need of utmost care in the planning and conduct of plat experiments. Assumptions of natural uniformity evidently are not justified.

Diversity found by the Indiana station in the results of analyses of samples taken from individual apple trees receiving identical cultural treatment led to a warning of the danger of drawing conclusions from limited material. A composite sample from at least 12 trees was required to show accurately the average composition of a group of 300 apple trees. That uniformity is needed in the preparation of samples for analysis was shown in studies at the Massachusetts station, where significant differences were obtained in the chemical study of dormant blackberry canes simply as a result of changes in the procedure of preparing samples for analysis.

Means of reducing variable factors have continued to occupy the horticultural investigator. As concrete evidence of this there are the carefully constructed low-temperature rooms at the university farm, California, and at the University of Minnesota which enable the maintenance of practically constant temperatures and humidities.

J. W. Wellington.

ECONOMIC ENTOMOLOGY

Research activities at the experiment stations relating to economic insects have continued to add much information of significance. Intensive studies of the life histories and bionomics of insect pests, both old and new, have been especially valuable in leading to the detection of their most vulnerable habits or stages. Particular attention has been paid to control with insecticides, the use of old forms in new combinations, and improved methods of application. The entomologist has found it necessary to adapt his activities to current conditions; it often happens that the insect under study becomes greatly reduced in numbers or disappears for a time while others become of major importance, and hence the work may be suspended or shifted from one insect to another.

The practical application of exact knowledge of the codling moth, gained through the investigation by the New Jersey stations of the factors influencing its development, is strikingly illustrated in the control obtained in the Glassboro district of New Jersey. In 1925, when organized efforts were first made to control the pest in that district, only 50 per cent of the total fruit was free from codling-moth injury and fruit growing returned little profit. The next year, working under the supervision of the New Jersey stations, the growers obtained 68.8 per cent of the fruit free from such injury,

and in 1927 81.1 per cent. In this control of the pest, timing, composition, and methods of applying insecticide materials were dominant factors.

The codling moth is highly variable in its development, the Virginia station found, its development being accelerated or delayed by extremes of high or low temperature. It was impossible to make correct recommendations for orchard treatment without occasional observations of the development of the insect. The studies at the New Jersey stations on the relation of effective day degrees of temperature to emergence of the larvæ conducted in six different years, have shown the average number of such degrees at the beginning of the first summer generation to be 1,339.9. In a comparison of codling-moth larvæ obtained from the Grand Valley of Colorado, where a form highly resistant to insecticides has developed, with the form occurring in Virginia, the Virginia station found that the Colorado larvæ had the greater ability to enter sprayed apples. When the strains were crossed the first generation of each cross was found to be less resistant to arsenical poisoning than the pure strain of Colorado larvæ but more resistant than the Virginia larvæ.

Investigations of the green citrus aphid in the central part of the citrus belt and on its extreme northern border by the Florida station have shown that severe outbreaks of the pest probably always will be confined to early spring, and especially to seasons characterized by a moist, warm winter free from destructive freezes, followed by a cold, dry spring which extends the flush of growth over an abnormally long period.

Larvæ of the oriental fruit moth were found by the New Jersey stations to overwinter in any kind of waste material in and around orchards. The majority of the larvæ were found in peach mummies, but proportionally there were as many in other protected locations.

Grasshopper studies at the Montana station have shown that the retardation of development of the eggs by high temperatures in midsummer and the acceleration due to low temperatures in the spring is of distinct advantage to the species, since the nymphal period is confined thereby to the spring season when green, succulent food is always available.

INSECTICIDES

Research with insecticides, now quite generally being conducted by the entomologist and chemist in collaboration, is contributing much to the advancement of the control of insect pests and opportunity in this field is still without limit.

Baits.—Continuing work with sprays for the control of the oriental fruit moth, the Pennsylvania station found the largest catches to result from the use of the molasses-water-sodium arsenite baits, where 1 part of molasses, 10 parts of New Orleans molasses, and 5 grams of sodium arsenite were used in each gallon of the mixture. This bait was found to be effective for at least 16 weeks, requiring only the occasional addition of water to compensate for evaporation.

Fish oil, the Delaware station found, is a cheap and efficient sticker for lead arsenate in the early sprays used to combat the grape berry and codling moths. According to results of the New Jersey stations, colloidal ferric oxide can be used advantageously as a sticker and possibly as an efficient corrective to eliminate arsenical injury. It is thought that the high adhesiveness of ferric oxide to peach and apple foliage may offer a solution to the problem of sticker and dust insecticides. An arsenical spray containing a commercial casein emulsifier as a sticker has given better results at the New York State station than the use of fish oil.

Fumigants.—During efforts to control the red scale which has become resistant to hydrocyanic acid gas, the California station found that when a spray is followed by fumigation a week or more later, satisfactory results can usually be obtained. This method was found to be more satisfactory than two fumigations or two sprays. The oil absorbs little if any of the hydrocyanic acid gas and acts as a protective film, with the result that higher doses of the gas can be used. Much less gas escaped through canvas covers when generated from the dust than from the liquid. The combination of liquid hydrocyanic acid gas with calcium carbide produced a very fine powder carrying 30 to 50 per cent of hydrocyanic acid, which did not injure the citrus foliage.

Dusts.—Dusting plants with sodium fluosilicate or calcium cyanide was found to give satisfactory control of the Harlequin cabbage bug at the New

Mexico station. The use of paradichlorobenzene against the giant apple root borer at the rate of 2 to 4 ounces per tree placed 5 or 6 inches from the bark destroyed an average of 50 per cent of the borers. In comparative tests by the California station, a 5 per cent nicotine dust proved to be the most practical means of controlling onion thrips.

Oils. — Oil emulsions containing either 40 per cent of nicotine or 0.5 per cent of crude cresol have completely controlled the European red mite and eggs of the apple aphids at the New Jersey stations, without damaging the host plant. Investigations have demonstrated quite generally the effectiveness of the mineral oils and have led to their more extensive use.

In control studies with the peach cottony scale, the New York State station found that undiluted white mineral oil No. 11 was the only material tested that killed eggs within the ovisac. White mineral oil emulsions at 2 per cent strengths proved the most effective sprays for midsummer treatment of this scale, one thorough application at the end of the egg-hatching period and before smutting of the fruits was evident giving commercial control. An application of this oil spray when the buds had begun to swell during early spring was found to be the most satisfactory control measure. Experiments extending over two years at the same station indicated that lubricating-oil emulsions, when carefully prepared and properly applied, are a supplementary method of combating the pear psylla.

The Oregon station found oil emulsions to give from 10 to 12 per cent better control of San Jose scale than did lime sulphur in years with unfavorable weather conditions. Four applications of 1 per cent white oil emulsion gave a reduction of 98.9 per cent in the number of European red mite eggs on peaches in New Jersey. In experiments at the New Mexico station 2 to 4 per cent red engine oil, with a commercial casein emulsifier, gave good results against the San Jose scale, was easily applied, and cost less than lime-sulphur.

Sulphur.—Sulphur dust was found to be superior to other dusts in the control of the cotton flea hopper in tests by the Texas station. Fall application of lime-sulphur at the rate of 1 part to 15 parts of water or stronger was found by the Oregon station to be effective against the blister mite on apples, and when applied in the spring to be more effective than oil sprays.

Arsenicals. — Further progress was made in work with the arsenical insecticides. In the control of the Mormon cricket the Montana station found that the use of calcium arsenite at the rate of 1 pound to 3 pounds of lime gave as good results as did the use of sodium arsenite and with a saving of 24 cents a pound for material. Calcium arsenate was found by the Alabama station to control effectively the adults of the southern corn root worm, and the application of an arsenate spray to infested pecans at the Florida station resulted in control of from 80 to 90 per cent of the leaf case-bearer. Magnesium arsenate applied by the New Mexico station at the rate of 2 pounds to 100 gallons of water or as a dust controlled the Mexican bean beetle.

Machinery.—The airplane as a means of applying insecticidal dust was used more extensively. The Texas station found this method of applying dust to be highly successful in the control of the cotton boll weevil. The Oregon station devised an apparatus for use in the application of insecticides by airplane to apple orchards and alfalfa fields.

Parasites.—Investigation on the biological control of insect pests has resulted in advances of considerable proportions. As a result of studies at the New Jersey stations, 47 hymenopterous and dipterous parasites of the oriental fruit moth were recorded. One of these, first reared from the strawberry-leaf roller, was an important factor in reducing the annual infestation in the Middle Atlantic States, since an average of 30 per cent of all the oriental fruit moth larvæ collected from May 1 to September 15 were found to be parasitized by it.

The total parasitism of the oriental fruit moth by the six species of larval parasites established in 11 counties of Ohio for 1927 was found by the Ohio station to reach 18.7 per cent. An ichneumonid parasite, *Glypta rufiscutellaris*, reared for the first time in Connecticut in considerable numbers, was more abundant than *Macrocentrus ancylivora*, hitherto the principal parasites of the oriental fruit moth. Parasitism was found to be a very important factor in suppressing outbreaks of the red-banded leaf roller in Virginia, 9 of its 19 known parasites having been observed in the State.

A method of laboratory production and increase of the Trichogramma egg parasite of the sugarcane borer has been devised by the Louisiana stations, and colonization of the parasites is under way.

INSECT TRANSMISSION OF PLANT DISEASES

The knowledge of the rôle of insects in the transmission of plant diseases, such as the various mosaics and leaf rolls, has advanced rapidly during recent years. The common potato leaf hopper, *Empoasca fabae* (Harr.), was shown by the Wisconsin station to be responsible for an affection of alfalfa known as "alfalfa yellows" or "yellow top." Extensive greenhouse trials at that station demonstrated that the green peach aphid readily transmits the cucumber-mosaic virus between tobacco and certain other susceptible solanaceous host plants.

Comparative trials under identical conditions have given no evidence of the transmission of the tobacco-mosaic virus by the same aphid between the same host species. It exhibits a definite selectivity in virus transmission; colonies reared upon tobacco plants, infected with both cucumber and tobacco mosaic, transmit only the cucumber-mosaic virus from the combination, although the tobacco-mosaic virus is present in the leaves upon which the aphids have fed.

An important discovery made by the California station of the connection between caprification of the Smyrna fig and the spread of the rotting or endosepsis of the fruit has furnished the basis for a practical method of control of this disease, which threatened the fig industry of the State. To follow the cycle it is to be remembered that fertilization of the Smyrna fig with pollen from the nonedible caprifig is essential to the production of fruit. This is brought about by the Blastophaga or fig wasp, which spends its early stages in the caprifig. There are three crops of the latter, one of which, the mamme or overwintering crop, ordinarily contains no pollen, and another, the profici, which bears an abundance of gall flowers and pollen and is available at the time when a brood of the Blastophaga are mature and the Smyrna fig flowers are receptive.

Following the discovery that the rot fungus is transmitted by the Blastophaga, the California station devised a plan for control of the disease by picking off all of the winter or mamme crop, cutting them open and dipping them in a fungicide to kill the organism of the rot. The Blastophaga emerging from these dipped mamme figs are caught in test tubes and distributed in the orchard for fertilizing the spring or profici crop, which is the one used to pollinize the Symrna fig. The picking off and treatment of infected winter (mamme) caprifigs was required by State and county authorities in 1928, providing another example of the practical application of research in solving a difficult problem.

William A. Hooker.

ANIMAL BREEDING

Substantial progress was made by the experiment stations in the study of genetic principles and their application in animal breeding. More refined and effective methods are being developed, and breeding practice is profiting to an increasing extent from the findings of research. The stations are now engaged in about 175 projects in animal breeding, divided about equally between investigations which might be classed as strictly genetic and inquiries which are less fundamental in character.

The many efforts made, particularly in recent years, to induce mutations at will or at a greater rate than they normally occur have generally given negative results. During the past year, however, X rays have been used successfully for this purpose, and several of the stations are preparing to test this means of artificially inducing mutations in plants and animals with the hope of obtaining results of practical as well as scientific value. The University of California has installed an X-ray laboratory for investigations of the possibility of modifying germinal and somatic tissue in plants and animals. This laboratory is available for cooperative investigation by workers in other parts of the country.

The Kansas station determined the rate of crossing over between barring, silvering, rate of feathering, and shank color—all sex-linked characters—from which the relative distances in the chromosome between the location of the genes responsible for each of these characteristics may be estimated.

Investigation at the Iowa station on the inheritance of plumage color, made by crossing White Plymouth Rocks with Black Langshans and Buff Orpingtons, and Black Langshans with Buff Orpingtons, gave results indicat-

ing the action of two pairs of factors upon buff plumage, the appearance of which was related to the balance between the color factor *C* and the factor for the extension of black, *E*. When both *C* and *E* were heterozygous with two doses of the buff factors, the color was buff, but when either *C* or *E* was homozygous dominant and the other heterozygous the color was black unless three or more doses of the buff factors were present, the birds then being buff. In these crosses white skin color acted as a simple dominant to yellow, these being inherited independently of the factors for colored and white plumage. This explanation of the inheritance of these colors may enable the breeder and fancier to produce birds of the desired color, and, further, he may test accurately the purity of his birds for these characteristics.

A striking case of hybrid vigor in poultry was reported from the Kansas station in which Jersey Black Giants were crossed with Single Comb White Leghorns. The hybrids surpassed both pure breeds in egg production, hatchability of the eggs, percentage of chicks surviving to 3 weeks of age, and in rate of growth to 12 weeks, but they were intermediate between the two breeds in growth to 6 months of age and in shank length.

Concurrent with the progress made in the study of the inheritance of various characters in practically all classes of animals and the perfecting of methods of genetic research, the field of investigation has been extended to embrace the study of the inheritance of productive capacity, quality of product, fertility, disease resistance, conformation, and other characteristics of economic importance, as well as color and like characters.

Significant findings have been reported in regard to the transmission of efficiency of performance and the genetic factors involved. The Missouri and Illinois stations, in particular, have shown that the ability of a female to transmit her capacity for milk production to her offspring may be more accurately measured by the average production of her sisters than by her own record. From a careful statistical study the Illinois station has estimated that the records of at least six daughters of a bull should be available before the bull is considered as tested for use as a proven sire.

According to the general results of studies in progress for a number of years at the Maine, Wisconsin, and Illinois stations, the inheritance of milk and fat production and various qualities of the milk through cross breeding is not simple, but each is controlled by several genetic factors. Investigations at the Wisconsin and Missouri stations have given indications that the factors for high production are mainly dominant.

Noteworthy advances have been made in the analysis and identification of factors responsible for various characteristics in poultry, such as color pattern, characteristics of the plumage, morphological characteristics, egg production, broodiness, comb characters, and many others. Although practical application has been made of known sex-linked characteristics in the identification of the sex of the chicks from certain crosses at hatching, no cases of autosomal linkage were known until the Connecticut Storrs station found several cases of linkage of this kind in crossing fowls of the silky type with Leghorns.

George Haines.

ANIMAL NUTRITION

In the solution of the problems of animal nutrition during recent years the experiment stations have made distinct advances along lines having a direct interest for the practical stockman as well as in the more primary scientific groundwork. The nearly 180 projects in progress at the experiment stations in this field of inquiry deal with the energy, protein, vitamin, and mineral requirements for growth and reproduction, and the influence of solar and other radiation upon nutrition.

The behavior of animals during fast, on varying planes of nutrition, and the symptoms manifested on subnormal rations, in experiments under controlled conditions, have given new insight into the reasons for conditions of animals long known but hitherto unexplained. The Pennsylvania station found that following any change of position of fasting cattle approximately one hour was required before the carbon dioxide in the outcoming air of the calorimeter became constant. A steer weighing approximately 470 kilograms produced 10.8 liters more carbon dioxide per hour while standing than while lying. The increase in heat production of the standing position over the lying position amounted to 15.1 calories per 100 kilograms of body weight per hour.

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Cutting off the food supply was found by the New Hampshire station to turn the demand for energy upon the organism itself, resulting in profound changes in the adaptation of the vital activities to the modified conditions. Steers were carried for three or four months on extremely low rations without affecting their health or ability to reach market condition with subsequent liberal feeding, showing that cattle have the ability to slow down or accelerate their vital activities in accordance with the available food supply. The food residues in the intestinal tract at times amounted to as much as one-fifth of the body weight of the animal and was assumed to be a source of energy. Respiration studies showed that the nitrogen losses are from the body proteins and that body fat supplies most of the energy for the body processes during fast. The so-called "hunger feeling" was found to be a temporary condition due to contraction of the alimentary tract, and after the second day no particular irritation or craving for food was manifested.

The Kansas station found that the lack of vitamin A in the diet of pigs causes a degeneration of the nervous system, characterized in advanced stages by impaired vision, extreme incoordination, and spasms. Histological examination of the nerves showed definite degeneration of some bundles in portions of the spinal cord, optic, sciatic, and femoral nerves. Eye lesions were present in extreme avitaminosis A, but were of minor importance. Avitaminosis A brought about irregularity in the oestrous cycle of gilts, the periods of heat occurring more frequently and being of longer duration than normal. Conception prior to the onset of the nervous symptoms was followed either by abortion or dead pigs at farrowing time. Vitamin C was not found to be essential for growth and reproduction of swine.

In the studies at the Iowa station fall pigs irradiated for 10 minutes daily with ultra-violet light grew rapidly, and the light reduced the amount of feed required per unit of gain. However, the cost of irradiation offset the advantage of saving in feed. Cod-liver meal cost more than it was worth nutritionally and during the early stages of feeding had a rather marked laxative effect upon the pigs, which, however, did not interfere with the pig's ability to gain. Steam-rendered cod-liver oil was markedly superior to sun-tried oil in rate and economy of gain.

The average coefficients of digestibility of the proteins, corrected for metabolic nitrogen, as determined with hogs at the Illinois station, was 85 for corn, 76 for tankage, and 82 for the mixture of the two. The average biological values for the proteins were corn 54, for tankage 42, and for the mixture 61. This study showed that while the crude protein of tankage had a low nutritive value, when combined with corn protein it had a marked supplementary value, and the mixed proteins had a slightly higher biological value than that of corn alone.

The exposure of chicks to sunlight filtered through glass substitutes was found to be effective by both the Ohio and New Jersey stations in preventing leg weakness. At the Ohio station such exposure increased the ash content 10 per cent over chicks not exposed. At the New Jersey stations winter sunlight radiated through glass substitutes was more effective in preventing leg weakness than exposure to the rays of a quartz mercury lamp.

The value of different feeds containing the antirachitic factor has been studied at the Wisconsin, Ohio, and New Hampshire stations. Cod-liver meals were found to vary in their antirachitic properties and the variations were not proportional to the residual fat content. The meals contained enough vitamin D to promote good calcification even when fed at a level of 1 per cent, but not enough vitamin A to protect against rickets even when fed at a 10 per cent level, although at this rate it retarded the onset of the rachitic symptoms. Fish meal contained enough vitamin D to prevent rickets for at least eight weeks.

At the Kansas station 2 per cent irradiated cottonseed oil had little if any effect in preventing rickets. Chicks exposed to sunlight filtered through ordinary window glass also developed rickets. Long exposure to the light of a mercury arc glass tube lamp which has no wave lengths shorter than 300μ prevented rickets.

For dairy cows on pasture the Ohio station found that a low-protein grain supplement was more economical than a high-protein ration, due to its lower cost and the failure of the high-protein ration to increase production. The gains of calves receiving milk from the high and low protein groups were approximately the same. The calves in the latter group tended to lag in

growth before the feeding of hay and grain started, but after that time no differences in growth were noted.

The milk from three cows that had been fed for more than two years at the Pennsylvania station on rations deficient in vitamin B was fed to rats on a vitamin B deficient ration. When the daily allowance was 12 cubic centimeters or more per rat, no pathological symptoms developed. It was evident that the vitamin B content of the milk is not dependent upon the presence of the vitamin in the ration, and it appeared that cows and possibly all ruminants possess the power to synthesize vitamin B.

Cows at the Ohio station were fed either 2 ounces of dulse (a seaweed), 0.5 grain of calcium iodide, or 0.5 grain of potassium iodide per head per day. Previous to the experiment the milk of these animals had shown no trace of iodine. After 30 days feeding traces of iodine were found in the milk, varying in amount from 1 part in 100,000,000 to 1 part in 10,000,000. As far as it was possible to determine, the source of iodine made little difference in the iodine content of the milk.

Henry W. Marston.

ANIMAL PRODUCTION

Recent experimental activities in animal production have taken a decided trend toward investigation concerned with basic principles and away from simple demonstrations. The empirical finding that two materials differ in feeding value will not suffice; inquiry must determine the causes and effects of such differences. The setting up of experiments under better controlled conditions has made for accuracy, and more rigid statistical analysis of the data obtained has strengthened the conclusions drawn.

The nearly 800 projects in animal production now in progress at the stations cover a wide field, ranging from physiology studies to observations of habits of animals and to the effects of environmental conditions upon the ability to do the work for which they are best suited. Special emphasis is being placed on the development of methods for making production more economical in order to meet changing conditions. The attainment of this end has necessitated more definite information for all classes of livestock on habits, physical structure, and the ability to respond to varying conditions.

The feeding of ruminants.—The dynamic factors involved in the physiology of the ruminant stomach were studied at the North Dakota station, where it was found that during the eating period cattle only partially and incompletely masticated both forage and grain, such that approximately 50 per cent of the kernels of shelled corn reached the stomach uncrushed. The movements of the rumen and reticulum are characteristic and well defined for each phase of activity. The motility of the peristaltic waves for these regions are slowest during rumination, increase perceptibly during the resting period, and are markedly accelerated while the animal is eating.

Rumination was found to depend upon proper stimuli, the nature and quantity of food present, and definite moisture conditions. Contrary to certain common belief, neither the esophageal grooves, special contractions of the rumen, nor abdominal muscles take part in regurgitation. The ingesta of the rumen and reticulum enter the omasum only when reduced to a certain finely ground condition. The ingestion of food diminishes the power but increases the frequency of the movements of the omasum, while rumination decreases the frequency but improves the regularity of these movements. The ingesta of the abomasum is always in a semiliquid condition.

Interesting observations of the activities of cattle, sheep, and goats while on range were made by the Texas station, which found that of the total feeding time cattle spent 33.3 per cent, sheep 27.5 per cent, and goats 7.1 per cent in grazing. Cattle spent 10 per cent, sheep 13 per cent, and goats 19 per cent of their day in travel, in which time they covered an average of 3.3, 3.8, and 6 miles, respectively. Cattle averaged 8 minutes per day in licking salt, while sheep and goats spent less than 3 minutes. In drinking water cattle averaged 2.4 minutes, sheep 1 minute, and goats 0.9 minute per day. It also was observed that cattle spent 9 per cent, sheep 10 per cent, and goats 11 per cent of the day in rumination while standing, 10, 11, and 8 per cent, respectively, in idling while standing, and 12.5 per cent of the day for cattle and 15 per cent for sheep and goats was spent in resting.

Cows that were strong and fat at the end of the grazing season were successfully wintered on straw alone at the Montana station, provided the weather was moderate and the feeding period

short. Supplementing the straw ration with 5 to 10 pounds of hay prevented extreme losses in weight during winter. One pound of cottonseed meal had approximately the same value as 5 pounds of hay in supplementing straw, but 1.5 pounds of oil meal per day was not enough to bring thin cows through a hard winter in good condition. Mature cows and yearlings maintained their weight during the winter on 40 pounds of sunflower silage per head daily plus free access to straw.

Sheep.—The difference in weight between lambs from high-milking ewes and good-milking ewes was found by the New Hampshire station to be 16 per cent, between high-milking and fair-milking ewes 38 per cent, and between those from high-milking and those from poor-milking ewes 79 per cent. The fat content of the milk was secondary to quantity in importance, lambs making corresponding gains on milk varying from 2 to 10 per cent in fat content.

Range ewes weighing from 80 to 100 pounds at the Montana station produced lambs averaging 21 pounds less at 148 days of age than did ewes averaging 130 pounds or more. The lighter ewes also averaged 1.5 pounds less wool. The percentage of twin lambs raised and the average weight of the pairs were higher for the heavier ewes. A mineral mixture composed of ground limestone, special bone meal, salt, and potassium iodide fed to ewes at the Ohio station had no apparent effect upon the vigor, condition, mortality, birth weight, and rate of gain of lambs, nor upon the milking qualities, mother instinct, and fleece weight of the ewe.

Swine.—Pigs fed alfalfa meal prepared by artificial drying or tankage cooked for 12 hours to destroy the vitamin A made satisfactory gains at the New Jersey station whether fed white or yellow corn in addition. The pigs receiving tankage made slightly more efficient use of their feed than those receiving alfalfa meal.

The Texas station demonstrated that not more than 12 per cent of cottonseed meal should be included in the ration of 57-pound pigs to be fed for 120 days. Sows fed rations containing 15 per cent of cottonseed meal remained in good health and produced as many pigs as sows fed tankage, but the pigs from the former sows grew less rapidly than those from the latter sows. Pigs self-fed a ration containing 15 per cent of cottonseed meal died from poisoning.

Brood sows fed ear corn, corn-and-cob meal, shelled corn, or ground corn gained practically the same at the Iowa station, and the rations had little or no effect upon the weight lost at farrowing time or upon the development of the pigs farrowed. Ground corn was not economical and corn-and-cob meal was no more satisfactory than ear corn or shelled corn.

Sows fed cocoa meal at the Vermont station developed rough hair coats, and at farrowing time approximately 25 per cent of the pigs were born dead. Of those alive at birth all were quite weak, and few lived over a few weeks. Sows fattened on cocoa meal gained rather slowly, but no significant differences could be found in the dressing percentage, meat, and flavor of the chops as compared to similar animals fattened on corn. Pigs fed cocoa meal did not make normal gains, and scours and general unthriftiness were common.

Hulled oats fed to hogs in conjunction with corn, tankage, alfalfa meal, and minerals at the Ohio station proved equal to corn in feeding value. In a palatibility test at the Illinois station hogs having free access to finely ground oats ate nearly twice as much oats and less corn and protein supplement and the rate of gain was lower than when coarsely ground oats were fed. For fattening hogs, oat kernels were more palatable than cracked or shelled corn, and hulled oats were nearly as palatable. It seemed that the whole oats must be cheaper than corn, pound for pound, before they can be fed profitably with corn in the ratio of 1 : 4 to fatten hogs. Under ordinary conditions it pays to grind oats rather than feed them whole, and whether hulling will be more profitable than grinding depends upon the cost of the two operations.

Pigs fed ground oats at the Minnesota station developed large middles and were rough coated and lacking in "bloom." The pigs fed oats required 87 per cent more grain and 102 per cent more protein supplement to produce 100 pounds of gain than those fed barley. The Illinois station found that oats could replace one-half the corn in the ration of sows without any apparent effect upon the number per litter, the vigor of the pigs at birth, or the capacity of the sows as mothers. More feed was required when oats were fed to keep the gains up to the standard of the corn-fed sows.

Early breeding and two litters a year combined with restricted feeding

retarded the growth of gilts materially at the Missouri station as compared with animals generously fed. Farrowing and weaning large litters caused sows to lose from 40 to 79 pounds in weight during the suckling period. Small litters caused litle change in weight, and when small litters were lost after farrowing the sows soon gained in weight. Losses in weight were greatest during the first four weeks after farrowing. Underfeeding the first month after breeding caused sows to farrow pigs which were below the average in size both at birth and at weaning. Early breeding of successive generations for 18 years has not affected the ability of the later sows to wean heavy pigs when properly fed.

Poultry.—Day-old chicks at the Oklahoma station averaged 68 per cent of the weight of the eggs from which they were hatched. While a definite relationship exists between the weight of the egg and the weight of the day-old chick, the latter weight is not held a reliable index of the weight at a later date. The rate of growth was largely independent of size at hatching and indirectly independent of the size of egg, environmental conditions exerting some influence on growth. The Illinois station found that chicks relatively large at 4 weeks of age were also relatively large at 8, 12, and 16 weeks of age.

The egg production of four of the principal breeds was studied over a period of nine years by the Connecticut Storrs station. The annual average for Wyandotte pullets was 159 eggs, for Rhode Island Reds 153 eggs, for Barred Plymouth Rocks 163 eggs, and for White Leghorns 158 eggs. Egg production gradually increased from November to February, with a high peak in March, April, and May, fell to a lower level in July and August, and suddenly declined in September and October, the molting season. There was a tendency during the nine years toward an increase in annual production and also an increase in production during the fall and winter, with a corresponding decrease during the spring and summer.

Feeding birds to induce heavy egg production just before the hatching season had no detrimental effect on the fertility or hatchability of the eggs or on the vigor of the chicks in tests at the West Virginia station. Eggs fertilized by mature males were found by the Massachusetts station to have a higher hatchability than eggs fertilized by cockerels. Yearling hens produced fewer eggs with a high hatchability than did pullets. No definite relationship was found between the age of the parents and fecundity.

Rations containing 20 and 32 per cent of cottonseed meal in tests at the Texas station produced eggs which began to discolor after four weeks in storage. An all-mash ration containing 9 or 12 per cent of cottonseed meal produced eggs with a similar tendency, whereas a regular ration containing 9 per cent and an all-mash ration containing 3 or 6 per cent of cottonseed meal produced eggs retaining good color for 28 weeks of storage. Eggs were not discolored as a result of feeding 1 per cent of crude cottonseed oil. At the New Mexico station birds receiving 38 per cent of cottonseed meal in the ration produced eggs with dark spots on the yolk after two months of such feeding. At both stations the danger of discoloration was lessened by feeding fresh succulent green feed.

Milk production.—The place of by-products of manufacture, e. g., cottonseed meal, cocoa meal, and linseed meal, in the ration of dairy cattle has been the subject of considerable investigation. The nutritive values have been determined for a number of these materials, and further inquiry is concerned with their economical use in milk production.

Cocoa meal, derived in the manufacture of cocoa and chocolate, was found by the Vermont station to reduce milk yield 11 per cent and to increase the fat test and the butterfat production 20 and 6 per cent, respectively. Certain of the constituents of cocoa meal, namely, cocoa butter, theobromine, and caffeine, were incorporated in the basal ration of the experimental cows. The cocoa fat had no effect upon the milk yield but increased the fat test 5 per cent and the butterfat production 4 per cent. The milk yield of cows fed theobromine was reduced 8 per cent, the fat test increased 8 per cent, and the butterfat production decreased 1 per cent. Caffeine feeding produced no significant effects. The response to feeding cocoa meal and theobromine was immediate, both at the beginning and at the end of periods on these feeds, while the response to cocoa fat was more gradual. Differences in the flavor of the milk or butter that could be attributed to the feeding of cocoa meal were not apparent, but butter made from cream obtained during the

feeding of cocoa meal had a firmer body and a higher melting point than ordinary butter.

A ration of cottonseed and wheat bran fed to cows at the New Mexico station produced somewhat less milk and slightly more butterfat than a ration of corn, wheat bran, and cottonseed meal. That the first ration was rather unpalatable was shown by the difficulty experienced in getting the cows to consume their full grain ration when changed from corn, bran, and cottonseed meal to cottonseed and bran. The reverse change caused no such difficulties, and there was less variation in the weights of the cows following the latter change.

Cows receiving linseed meal as the protein supplement in Minnesota station tests averaged 149.7 pounds of milk and 5.75 pounds of butterfat per 100 pounds of digestible nutrients fed. When ground soybeans replaced the linseed meal in the ration the average production was 145.7 pounds of milk and 5.86 pounds of butterfat. The average fat test while the cows were receiving linseed meal was 3.82 per cent, and while they were receiving ground soybeans it was 4.01 per cent.

That the quality of milk depends on environmental factors as well as on feed was observed by the Iowa station, which found that the fat percentage of milk varied definitely with the seasonal changes, being highest during the first half of the winter, gradually declining to the last half of the summer, and rising rapidly in the fall. The butterfat test varied inversely with the inside and outside temperatures of the barn, and there were indications that outside temperature was more closely correlated with fat test than was inside temperature. Fat tests tended to be high just after freshening, declined for two or three months, and then rising during the rest of the lactation period.

Withholding feed from cows for a period of five to six days caused a decided reduction in the milk yield during studies by the Illinois station, the decrease being especially rapid during the first three days. As the milk yield decreased the percentage of all the components of milk, except lactose, increased. The changes were not so marked when feed was withheld early in lactation as when they were later withheld in lactation.

HENRY W. MARSTON.

DAIRY MANUFACTURE

The rapid rise in the consumption of dairy products during the past decade in large measure has been responsible for the opening to investigators of a broad field practically untouched in many phases. Ice cream is an especially good example. Much has had to be learned in regard to the causes and control of conditions which arose with the increase of volume of product and with introduction of improved machinery. Methods for the control of quality and for the increase in quantity of the product derived from the raw material, developed from the results of investigations by the station, are being used extensively under practical conditions.

The 120 projects in the field of dairy manufacture deal with such problems as the cause and control of defects in milk, butter, cheese, and ice cream, the making of better and more attractive dairy products, and the development of promising new methods and products.

Ice cream.—With increase in the overrun of bulk ice cream, in Maryland station studies, came decreases in the number of quarts dipped from a 5-gallon can and in the weight per quart. The quantity of gelatin present had practically no effect on the dipping losses. A fat content of 15 per cent decreased losses slightly, while sugar and milk solids-not-fat contents of 18 and 12 per cent, respectively, caused greater dipping losses. The most satisfactory temperature for dipping a standard mix was 8° F. or lower, when the overrun was approximately 90 per cent. Dipping below 8° gave quarts weighing less than quarts dipped at 9 to 16°, but this loss was offset by the fact that the product remained firm for a longer period.

Increasing the milk solids-not-fat in an ice-cream mix caused an increase in the apparent viscosity in tests at the Michigan station. The solids-not-fat had little or no effect upon overrun but did increase the specific gravity and lower the freezing point of the mix. Ice cream having 10 per cent of milk solids-not-fat was the most desirable product, retaining its smoothness of texture and firmness of body even after periods of storage. Both 6 and 12 per cent gave products with certain undesirable qualities. Increase in fat hastened the time in which the maximum quantity of air is whipped into the cream and raised the score for flavor, body, and texture, but de-

creased overrun. Ice cream with low fat content decreased in quality during storage.

The fat and serum solid content had little effect upon the whipping quality of an ice-cream mix at the Wisconsin station. Sugar, gelatin, and egg solid usually increased the whipping time, and homogenization and aging for 24 hours produced a decided improvement in the whipping ability. The whipping ability of a mix seemed to limit the stiffness to which the product might be frozen.

Adding gelatin with a high bacterial content to an ice-cream mix after pasteurization may noticeably increase the plate count of a sample. However, it was found that gelatin when pasteurized with the other ingredients was a negligible source of bacterial contamination. Sugar added before homogenization increased the viscosity to a greater extent than when added after homogenization. Fat was more highly dispersed, however, when sugar was not present during homogenization. Adding sugar after homogenization increased the ease of obtaining overrun, decreased the resistance of ice cream to melting at room temperature, and had no effect upon the body or texture of the finished product.

Cheese.—Comparing methods of pasteurizing milk for Cheddar-cheese making, the New York Cornell station found that the flash method destroyed 98.31 per cent of the bacteria present in the raw milk, the flash-holder method 98.65 per cent, and the holder method 98.96 per cent. Milk pasteurized by the holder method produced the most cheese per 100 pounds. Cheese made from pasteurized milk scored higher than that made from raw milk, and cheese from the flash-holder method made the greatest increase in score. Addition of calcium chloride to the milk increased the yield and the quantity of fat incorporated in the Cheddar cheese and so stimulated the action of the rennet that it was necessary to reduce the quantity ordinarily used by one-half. Apparently such cheese did not differ in flavor or texture from cheese made by the usual method.

Buttermilk.—Buttermilk drinks, to which were added either 0.1 or 0.25 per cent of gelatin at the Missouri station, did not whey off during the time the product is customarily retained. Larger quantities of gelatin gave a product which developed a very firm body on standing and a slight yellowish color. Gelatin had no apparent effect upon the flavor or aroma. Metallic flavors, produced in buttermilk at the Iowa station when *Streptococcus lactis* and *S. citrovorus* or *S. paracitrovorus*, all starter organisms, were present, developed under the proper conditions even when the buttermilk was in glass containers and developed more readily in buttermilk than in any other dairy product.

Cream.—In a study of physical factors influencing the formation and fat content of gravity cream, the New York Cornell station found that individual fat globules rose so slowly through the milk plasma that they required many times the normal creaming time to reach the cream layer. The individual globules fuse into clumps, estimated to contain slightly less than 50 per cent of fat by volume, which rise rapidly enough to account for normal creaming time. The observation that the fat globules pack into clusters and the clusters into the cream layer with volumes free from fat between them explained the low fat content of gravity cream. Large, irregular clusters form deep layers, while compact and especially weak clusters form shallow cream layers with a high fat content. As the creaming temperature increases the rigidity of the clusters lessens, and allows closer packing, thus accounting for the deeper cream layers obtained at low temperatures.

Feathering of cream, according to tests at the Illinois station, appeared to be due to the precipitation of calcium casein by heat. The use of hard water, which usually contains calcium salts, causes a disturbance of the salt balance and results in feathering. This was confirmed by the observation that sodium citrate reduced the tendency to feathering when hard water was used. Adding calcium chloride increased the tendency. The fact that just after freshening and toward the end of lactation cows produce milk high in minerals, especially calcium and phosphorus, and containing smaller quantities of citric acid seemed responsible for seasonal variations in feathering.

Whipping cream, the Missouri station found, should contain 32 per cent butterfat and should be aged from 24 to 48 hours at 42° F. and also whipped at 42°. Adding from 4 to 6 per cent solids-not-fat to cream to be whipped increased the overrun, shortened the process, and improved the luster, body, texture, and flavor of the finished

product. Homogenization even at low temperatures failed to increase the overrun, and each increase in pressure lowered the overrun, prolonged the required whipping, and resulted in a less stable product.

Henry W. Marston.

VETERINARY MEDICINE

Investigations at the experiment stations on the diseases of livestock continued to be productive of significant information. Particular attention was paid to pullorum disease of the fowl and abortion disease of cattle. The increased activity in research in avian pathology was notable.

Infectious abortion.—Further advancement in the elimination of infectious abortion from station and private herds was reported by a number of stations. Herds previously operated at a loss, according to the Connecticut Storrs station, became paying investments through the elimination of infectious abortion. At that station the milk yield of a nonreacting herd averaged 1,505 pounds more of 4 per cent milk per cow in a 12-month period than a previous herd which had contained both reacting and nonreacting cows.

Abortion-infected cows were found unprofitable by the Oregon station because they gave less milk, had more garget and more breeding trouble, developed more cases of chronic inflammation of the joints and lameness, and produced fewer live calves. Infected animals did not develop an immunity, and the disease did not disappear. Eradication from the station herd was accomplished by separating the reactors from the nonreactors, raising abortion-free calves to replace the infected animals, cleaning and disinfecting the barn, and testing frequently and removing all new reactors before they became dangerous.

The freeing of a badly infected herd in about two years through the application of suitable methods of sanitation and quarantine and periodic application of the agglutination test was reported by the Georgia station. This was accomplished in spite of the fact that most of the time the cattle had been kept in lots adjacent to other lots containing badly infected cattle retained for other studies. The elimination of infectious abortion by methods of segregation and herd management worked out by the Washington station continued to be effective, not a single case of infection occurring in nearly four years.

The Illinois station has obtained further proof that sanitation and testing have done more to control infectious abortion than all the other procedures employed. The agglutination test for the detection of *Brucella abortus* has been found to be as accurate a means for diagnosing infectious abortion as the tuberculin test is for tuberculosis. Approximately 90 per cent of all cattle abortion coming to the attention of the investigators at that station was said to be traceable to *B. abortus*.

In further efforts to perfect the agglutination test, the Connecticut Storrs station found that by using a buffered solution in the preparation of the antigen the incubation period could be shortened from 48 to 12 hours. A comparative study of strains of the abortion organism of porcine, bovine, and human origin and *B. melitensis* of human and caprine origin showed that true bovine strains are sharply marked off from the other strains when grown in glucose cultures. The Michigan station demonstrated that the antigen previously recommended for use in the rapid agglutination test in abortion disease is too sensitive, and that this condition can be modified by increasing the concentration of the antigen. Results obtained from several thousand tests indicated that its accuracy and specificity are equal to any other method. Reinfection is evidently an important factor in second and third abortions, the Oregon station's studies of economic losses indicating an average decrease in production of from 20 to 25 per cent following infection.

In its immunity studies with infectious abortion, the Washington station obtained the most promising results from the use of live cultures injected subcutaneously into heifers two months before they were bred, although this method of immunization seemed far from being completely satisfactory. The California station demonstrated that the vaccination of cows with a living virulent culture of the abortion organism will confer resistance to this form of abortion for at least three regular gestation periods, but such vaccination may cause a localization of the infection in the udder and the germs may be discharged in the milk. In work with a bacterin for equine abortion at the Kentucky station, one made from *Bacterium abortus*

equi was administered to 1,799 mares on 53 farms and was found to protect them from the disease.

The discovery that *Brucella abortus*, the cause of infectious abortion in cattle, may be responsible for undulant fever in man has resulted in an extensive activity in this field, several stations making important contributions. The porcine strain of the organism, which at times occurs in the bovine, has been found the most pathogenic for man. According to the Michigan station, this held true regardless of the source of isolation, whether from hog, cow, or man.

The Connecticut Storrs station found that *B. abortus* of bovine origin utilizes very little or no glucose, while *B. abortus* of porcine and of human origin and *B. melitensis* consume from 4 to 18 per cent of the available carbohydrates for growth energy. This difference in sugar metabolism provided a means of differentiating the bovine type from the human and porcine and from *B. melitensis* by the different amounts of the various nitrogen fractions present in the culture medium over a 14-day incubation period, the difference being apparent only in the glucose-containing media.

Pullorum disease of fowls.—Contributions to the advancement of knowledge of the pathology, diagnosis, and means of control of bacillary white diarrhea, or pullorum disease of the fowl, came from an increasing number of stations. Studies at the Wisconsin station showed that eggs from the pullorum-infected hens do not hatch nearly as well as those from noninfected hens, the difference in hatching in favor of noninfected hens being 7.2 per cent.

A comparison of diagnostic tests showed the agglutination tests to be more accurate than the pullorin test. The first report on the pathogenic effect of this organism in the turkey was published by the Minnesota station which found it to cause the loss of all the baby poults in a large flock. The pathogenic effect of *Salmonella pullorum* upon the rabbit was observed by the Nebraska station, which recorded the loss of some 125 rabbits that had been fed infertile infected eggs that had been incubated for 18 days. In a contribution on the differentiation of *S. pullorum* and related organisms, the Michigan station described a dextrin-lactose-agar medium which makes possible an accurate identification of any suspected culture in 48 hours. The same station found that brilliant green, when added to nutrient agar, allowed unrestricted growth of *S. pullorum*, *S. gallinarum*, and all other members of the paratyphoid group, and had a selective inhibitory effect upon *Baci lus coli*.

Additional knowledge of the pathology of the disease was contributed by the Indiana station from studies over several years, which led to the conclusion that the disease has a remarkably definite pathology and can usually be diagnosed by the gross lesions. The only cases in which lesions of this disease were found in the absence of demonstrable *S. pullorum* infection were those in which another paratyphoid organism such as *S. gallinarum* was the infecting agent. Lesions of the disease of chicks were found in the liver, lungs, heart, ceca, and gizzard. It was pointed out that any type of pneumonia in chicks strongly suggests white diarrhea, and that gray or yellowish nodules in the lungs can be considered pathognomonic of the disease. Gray nodules in the heart wall and in the gizzard were found to be very reliable indications of the disease. Lung lesions were reported by the Indiana station to be produced by dusting chicks with sterile alfalfa dust that had been infected artificially with *S. pullorum*. As high as from 30 to 85 per cent of the chicks from infected flocks showed lesions of the disease in the lungs at autopsy.

Diagnosis of pullorum disease.—A large number of stations reported progress in studies of the agglutination and pullorin tests for the diagnosis of the disease. Its observations led the Colorado station to suggest that the agglutination test be applied at more frequent intervals. The station found that while the test is not 100 per cent accurate it is the most promising plan yet advanced for eradicating the disease. In the cooperative testing of birds for bacillary white diarrhea by means of the agglutination test, the Minnesota station found that the efficiency of the individual laboratories for detecting infected birds was relatively high. Most of the discrepancies found in the negative and suspicious zones evidently were caused by the so-called "close" reading, in which slight clumping or a partial agglutination in one or more dilutions is interpreted as a positive reaction by some and disregarded by others.

The Kansas station reported that the rapid macroscopic agglutination

test is as efficient in detecting reactive fowls as the tube methods, and can replace them. This station concluded that the pullorin test in its present stage of development can not be recommended to replace the current agglutination methods in diagnosis. However, there appears to be a promising field for further research in an attempt to reduce the cost of the test.

In studies of the agglutination tests the Michigan station found that an antigen containing sodium hydroxide is superior to the other antigens used since it gives the clearest reactions, shows no tendency to produce proagglutinations, and almost entirely eliminates cloudy reactions. Formalinized antigen produced very indefinite reactions, showed marked zone phenomena or proagglutinations, and seemed decidedly lacking in sensitiveness. The rapid test promised to become the most practical and useful test employed in the control of the disease.

The North Carolina station observed a marked difference in the agglutinability of strains of the bacillary white diarrhea organism isolated from various sources. In the strains secured from chicks dying of the disease the agglutinability was greater than in strains secured from infected chicks dead in the shell on the twenty-first day, from infected eggs, and from lesions in adult carrier birds. It was concluded that strains developed for antigenic purposes should be selected relatively according to this grouping. There appeared to be a tendency toward a greater concentration of antibodies as the birds mature and as the infection becomes more pronounced.

The elimination of inaccuracy caused by cloudy reactions was considered by several stations. The Minnesota station found birds characterized by blood serum which remained cloudy for eight months, although there were intervals when the cloudiness was not pronounced. A study of the incidence of cloudy reactions for *Salmonella pullorum* infection at the Arkansas station showed clearly that they appear earlier than the agglutination reactions. Since the cloudy reaction tended to persist, a selection of the time of reading did not offer a means of avoiding the interference of this nonspecific precipitation. During investigation with the agglutination test the Massachusetts and Minnesota stations found that bacterial contamination by rod-shaped organisms affected its accuracy. The addition of boric acid to the solution in tubes in which the blood was drawn was found by the Minnesota station to act as a preservative, and its use was recommended.

The Connecticut Storrs station observed that antigens employed in the agglutination test in which formalin was used were useless. An antigen containing sodium hydroxide prevented the formation of cloudy precipitates and checked closely with the ordinary carbolized antigen. It appeared, however, that the sodium hydroxide antigen is slightly more sensitive than any that had been tried. In four years' studies of the resistance of chicks to the pullorum disease, the Illinois station found the existence of hereditary resistance to be supported by consistent difference in survival between selected and unselected lines, higher survival among inbred than among noninbred flocks, and consistent performance of individuals during successive years on the basis of survival of progeny.

Other diseases of cattle.—Investigation of red water disease of cattle known as bacillary hemoglobinuria, conducted by the Nevada station, led to the preparation of a vaccine, now available for use, for the prevention of serious losses over a period of at least six months. The use of a curative serum prepared at the station resulted in recoveries averaging about 75 per cent as compared with a death rate of about 100 per cent of those not treated. By feeding bone meal and fine salt mixtures, the Texas station found that it is possible to practically eliminate hone chewing on the range, and that when bone chewing and consumption of putrid carcass material are eliminated the trouble from loin disease disappears.

A method devised by the Wisconsin station for the detection of the human type of streptococci in milk led to the differentiation of the many harmless bovine types that are common in nearly all milk samples. This station found that inherited skin defects of calves are the same as those which occur in calves in the Netherlands. This condition, found in herds having certain blood lines, was designated as epithelio-genesis imperfecta neonatorum bovis. The Montana station found that there is a great variation in the virulence for sheep of both cattle and sheep strains of the blackleg organism. A strain of the organism that has become avirulent in the lab-

oratory was found the most reliable agent in immunizing sheep against the disease.

Lunger disease of sheep.—The "lunger" disease of sheep was indicated by the Montana station as probably of bacterial origin, a predisposing cause being an irritation of the respiratory tract due to conditions under which sheep are managed. Infectious dysentery of very young lambs was discovered by the same station to be caused by *Bacillus welchii* and apparently transmitted by the mother's milk.

Fowl pox.—Contagious epithelioma or fowl pox, one of the most important of the avian diseases, was investigated by a number of stations. The Massachusetts station demonstrated that the specific antibody concentration in the blood serum of immune fowls was not the sole protective force against the disease, a cutaneous immunity being of prime importance. The experiments with local or cutaneous vaccines included work on their standardization, and a tentative standard was adopted. It was decided that the virus to be used should have an incubation period of from four to seven days, and, therefore, must be less than 1 year old. The vaccine should contain 200 milligrams of such a virus suspended in 50 cubic centimeters of a 40 per cent glycerol-physiological saline solution, and the product should be used within 25 days after its manufacture.

The western Washington station reported satisfactory results from the use of a vaccine consisting of pulverized chicken-pox scab in physiological saline solution with 0.5 per cent phenol, and glycerine, applied with a swab to feather follicles. This work showed that chickens could be immunized against subsequent inoculation with the virus, the immunity lasting at least two years and probably during the life of the birds. The application of this vaccine to 4,000 White Leghorn pullets averaging 60 per cent egg production led to an egg reduction of about 20 per cent and a mortality of some 5 per cent with a return to normal at the end of a 3-week period.

The immunity obtained by the subcutaneous injection of the vaccine perfected at the California station was found to last as long as 275 days. The immunizing value of the vaccine was shown to depend upon and to vary according to the quantity and virulence of the virus contained.

Fowl paralysis.—Studies of paralysis of fowls, a disease increasing in importance in recent years, indicated that there are several forms due to as many inciting agents. The New Hampshire station concluded that coccidiosis in most instances is closely associated with paralysis in that State. The station found evidence of immunity development against coccidiosis among birds that had recovered from paralysis. In studies of several enzootics of tæniasis due to *Davainea proglottina*, a species not exceeding one-eighth inch in length and rather uncommon in the United States, the Kentucky station found that the birds containing large numbers of the tapeworm were in flocks in which range paralysis was reported as the principal trouble.

The Indiana station found that the virus of fowl paralysis is transmitted through the egg, although the disease is not produced by inoculation. Several chicks hatched from eggs laid by the infected flock developed typical paralysis before they were 2 months of age.

Avian tuberculosis.—Considerable activity in investigational work with avian tuberculosis and its occurrence in swine was reported. The Illinois station observed that an important part of the tuberculosis of swine in that State is of the avian type, and that cattle are mildly susceptible. Current studies at the Minnesota station showed that the danger of transmission of avian tuberculosis through naturally infected eggs is of little practical consequence.

Parasites and parasiticides.—The various intestinal parasites are responsible for much of the loss sustained by poultrymen. Feeding experiments with embryonated eggs of the cecal worm at the Oregon station led to the production of mature forms in 30 days. The cecal abligation operation for the prevention of blackhead of turkeys perfected at the Missouri station continued to give good results and to show its effectiveness as a preventive of the disease under natural conditions. In further studies of Manson's eye worm in the fowl, which is transmitted through feeding on the cockroach, the intermediate host, the Florida station found that the larvæ in passing through the crop to the gizzard are macerated and killed by the muscular action and by the grit. A number of common birds as well as the pigeon have been infested through feeding on

roaches containing larvæ of the parasite.

In a study of coccidiosis, one of the most important poultry diseases, the Oregon station found that birds will void oocysts in their droppings for a maximum of from 30 to 40 days following infections. A very definite immunity was produced through the administration of gradually increased numbers of the organism. Inoculation experiments demonstrated that birds raised on range under commercial-flock conditions and management frequently acquire an immunity against coccidiosis, and it was considered probable that this immunity is a result of continuous exposure to small amounts of the infection.

In preventive work against the tapeworm, a source of loss among chickens, the New Jersey stations found that birds reared in confinement and protected with fly screen gave a markedly greater production. No case of tapeworm infestation was detected in the protected lot. A further study of the effect of chemicals for the control of important diseases by the Rhode Island station showed that commercial hypochlorite preparations had no apparent germicidal action in the alimentary tract. However, they acted as efficient disinfectants of the drinking water, and in this way apparently would prevent the spread of disease.

Plant poisoning.—Plant-poisoning inquiries involved poultry as well as cattle. The Kansas station reported upon studies of the loss of poultry in 24 to 48 hours following the first symptoms after feeding on death camas. In a study of the poisoning of poultry by the coffee bean, the Florida station found that the loss may be prevented by picking the seed pods before maturity. The poisoning of sheep by western chokecherry, which occurs soon after drinking from mountain streams, was found by the Nevada station to be due to the liberation of the toxic principle from the chokecherry leaves by the excess of water present in the stomach.

This station also found that when hungry sheep are permitted to satisfy their appetite quickly and completely by feeding on greasewood, poisoning and death may follow. The work showed that excessive rainfall in the spring produces a moist and sappy condition of the slender fleshy leaves, rendering them devoid of any discoverable poisonous properties. In years of drought, however, the sap is so much more concentrated that it is apt to cause a fatal poisoning of sheep that feed heavily on the leaves. The first visible symptoms appeared in about three and a half hours after sheep were fed a toxic or a fatal quantity of the plant, although in a few of the sheep symptoms appeared in less than two hours.

In a study of sweetclover-hay poisoning, the North Dakota station perfected a method for testing the toxicity of hay which is based upon the fact that rabbits are affected more readily and much earlier by the poisoning than are cattle under the same conditions of feeding. A large majority of the rabbits arrive at the bleeding stage and die within 6 to 20 days earlier than cattle fed the same material. The plan for testing consists in the feeding of a hutch of four or more tame rabbits on the hay in question at the same time it is being fed to cattle. The hay should be selected each day from the same spot, place, or layer of the stack or mow so that both classes of animals will be eating the same kind of hay. Any of the rabbits dying are to be sent to the station pathologist at once and the cattle removed from the damaged sweetclover. If any of the rabbits die in from 6 to 7 days after feeding on a specimen of hay, it is considered doubtful whether such hay should be used for livestock, whereas if the rabbits continue to eat the hay for 2 weeks or more before they die, the feeding trials indicate that it can be fed with comparative safety to horses, sheep, and older cattle as part rations or by alternating it with reliable feeds.

William A. Hooker.

FOODS AND NUTRITION

The agricultural experiment stations have played an important rôle in showing the significance in nutrition of what is sometimes referred to as the "infinitely little." It was largely through the early studies at the Connecticut and Wisconsin stations that the vitamin hypothesis was first established. Recent developments have indicated that certain inorganic elements are also required in proportions so small as to be included in the term "infinitely little."

One of the two distinct types of vitamin research in progress at the stations deals with the content of the known vitamins in natural foods and feeding stuffs with reference to various cultural and manipulative practices, and the other is concerned with funda-

mental investigations of the nature of the different vitamins and the way in which they function.

Vitamin content of foods.—Most of the studies of this type are proceeding as home economics projects under the national cooperative project on the vitamin content of foods in relation to human nutrition. The special vitamin committee of the Association of Land-Grant Colleges and Universities formulated during the first year of operation of the Purnell Act an outline of the various factors which might be considered as to their effect upon vitamin content and made certain suggestions concerning approved technic for such studies. As the result of this activity, a considerable number of studies on vitamin content with more or less uniform technic are under way throughout the country. A few of the earlier studies have been completed and reported on.

The phases of the vitamin problem recommended by the committee for cooperative inquiry were the effect of variations in methods of production and methods of handling upon the vitamin content of foods.

The earlier study on the vitamin A content of head and leaf lettuce at the Michigan station has been followed by one on the vitamin A in bleached and green asparagus. This showed also an apparent association between vitamin A and greenness in plant tissue; the green tips of asparagus, fed either raw, freshly cooked, or canned showed a relatively high content of vitamin A, while the bleached tips showed no appreciable quantities of this vitamin. Other studies at the same station deal with the effect of different nutritive conditions, as controlled by fertilizer treatments, on the vitamin A content of lettuce. Through a cooperative arrangement between the Rhode Island and Pennsylvania stations spinach grown at the former station on soil which has been fertilized under known conditions for many years is being dried and sent to the latter station for vitamin analysis.

The Wisconsin station has reported that greenhouse tomatoes are as rich in vitamin C as the same variety grown out of doors and that ripe tomatoes contain much more vitamin C than green tomatoes even when the tomatoes are ripened in the dark after removal from the vines. A more elaborate study at the Iowa station of the effect of various methods of ripening on the content of vitamins A, B, and C in tomatoes showed that green mature, air-ripened, vine-ripened, and ethylene-ripened tomatoes contain the same amount of vitamin B, that ripe tomatoes contain more vitamin A than green tomatoes but that the method of ripening is immaterial, and that ethylene-ripened and air-ripened tomatoes are richer in vitamin C than green tomatoes, but are not as rich as the vine-ripened fruit. Ethylene-bleached celery was found at the Maine station to be as rich in vitamin B as green celery.

Investigation at the Illinois station on the distribution of vitamins in the cereal grains was extended to the vitamin-A content of the milling products of yellow corn and vitamin B in the structural parts of the oats kernel. The greater part of the vitamin A of yellow corn was found to be located in the pigmented layer of the endosperm. This could be almost completely recovered in the gluten which is rich in vitamin A. Vitamin B was found both in the embryo and the endosperm parts of the oats kernel, but in slightly greater concentration in the former.

Two varieties of native-grown dates, the Deglet Noor, a semidry cane-sugar date, and the Haynay, a fresh, soft, invert-sugar date, were found by the Arizona station to contain vitamin A and vitamin B. The concentration of both of these vitamins was lower in the Deglet Noor than the Haynay variety. The differences were thought to be due to the time of picking (ripeness) and method of maturing (pasteurization) which are different for the two varieties. Preliminary studies at the California station suggested that there is less loss of vitamin C in peaches and prunes in the drying or evaporating process when sulphured than when unsulphured.

Early Richmond cherries canned by the open-kettle method in 1926 and 1927 at the Kansas station were found to be slightly richer in vitamin A than the same variety canned by the cold-pack method in 1927. Studies under way may indicate whether the difference is seasonal or attributable to different methods. Yellow Elberta peaches canned by the cold-pack method proved richer in vitamin A than white peaches canned in the same way.

Further studies at the South Dakota station on the vitamin C content of canned spinach leaves demonstrated that less loss of this vitamin occurs when the spinach is blanched for 2

minutes in boiling water and processed for 70 minutes at 15 pounds pressure than with the usual procedure of blanching in steam for 15 minutes and processing at 15 pounds pressure for 90 minutes. At the Michigan station the blanching process was found to bring about some destruction of vitamin A and a more rapid loss in vitamin B in peas subjected to the usual canning processes. In the case of vitamin B the usual method of blanching 5 minutes and processing 40 minutes resulted in a 45 per cent loss as compared with only 25 per cent when the blanching was omitted. As is evident from this brief review, the content of any particular vitamin in any food is not fixed but may vary with cultural conditions and different manipulative treatments.

Vitamin requirements for reproduction and lactation.—In the earlier days of vitamin research it was considered sufficient to carry out feeding experiments for the most part only through the period of growth, with satisfactory growth and development as the criteria of a complete diet. However, when such experiments extended into the second generation, it was discovered that diets quite satisfactory for growth of a single generation may be inadequate for reproduction and lactation. It was found that a deficiency in vitamin A or vitamin B interferes with reproduction.

Studies by Evans at the California station and by Sure at the Arkansas station demonstrated that while vitamin A and vitamin B are required for the initiation of reproductive processes, vitamin E, hitherto unknown, is responsible for the completion of these processes. In the absence of vitamins A or B implantation of the ova fails. In the presence of vitamins A and B, but with the absence of vitamin E, gestation may be normal until shortly before parturition, when there is resorption of the fetus. The Arkansas station reported that sterility of the same type as that produced by deficiency in vitamin E can also be produced in rats on diets furnishing an abundance of vitamin E in the form of wheat oil but no vitamin A except the small quantity present in the wheat oil. In the complete absence of vitamin A, however, gestation does not proceed to this point. At the California station, however, it was still maintained that the specific effect of lack of vitamin A is the failure of fertilization and implantation and if, as in the case of about one-fifth of the copulations, implantation does occur, gestation is completed, and normal litters are born. Earlier evidence of the constant appearance of cornified cells in the vaginal smear of rats suffering from vitamin A deficiency was confirmed, and this was shown to be due to lack of vitamin A rather than to lack of vitamin E. The character of these cells was thought to afford further proof of impaired or inadequate internal secretion in vitamin A deficiency.

The claim that withdrawal of vitamin B (chiefly the antineuritic) factor from the diet of male rats is followed by degenerative changes in the testes was disproved at the California station by two types of experiments—one involving long-continued feeding on diets furnishing inadequate amounts of vitamin B, with an abundance of vitamin E, and the other complete deprivation of vitamin B. Although sterility was demonstrated after mating with fertile females, there was no evidence of actual injury to the testis, the sole injury to the productive function apparently being a decrease in sex interest. Degenerative changes noted by other investigators were attributed to inadequate vitamin E in the experimental diets. So much emphasis has been given to the effect of lack of vitamin E on the sex glands that the possible growth-promoting property of this vitamin has received little attention. The California station demonstrated, however, that vitamin E has a favorable effect upon the final stage of growth (growth after sexual maturity) in both male and female rats and that this takes place even after removal of the sex organs.

Further evidence of a much greater need of vitamin B for lactation than for growth has been obtained both at the California and the Arkansas stations. It has been demonstrated at the former station that as a source of vitamin B for lactation, 15 per cent or more of yeast is barely sufficient and 10 drops of tikitiki extract daily is inadequate, but that a combination of 0.6 gram of yeast with 3 drops of tikitiki extract renders the diet entirely satisfactory. Since the California station has demonstrated that tikitiki is rich in vitamin F (antineuritic) but practically free from vitamin G, it appears probable that the supplement needed for lactation is vitamin F rather than vitamin G.

This would also seem to be indicated by the beriberilike symptoms observed at the Arkansas station in

the nursing young of rats on diets furnishing sufficient wheat embryo as a source of vitamin B for growth but not for lactation. Partial to complete loss of control of the rear limbs was observed to occur with great regularity. In most cases the stomachs were found to be well distended with curd, showing that the failure of lactation was due to poor quality rather than deficient quantity of milk. Hemorrhagic conditions were present in the bony tissues and occasionally in the internal organs. A striking similarity has been noted in the literature between these symptoms in rats and the symptoms of infantile beriberi and malnutrition, and the belief is growing that the diet of infants, whether breast fed or artificially fed, should be supplemented regularly by some rich source of vitamin B.

The differentiation of vitamin B.—Further evidence that what was formerly known as vitamin B is composed of at least two and possibly more independent vitamins has been reported from the Alabama, California, Ohio, and Missouri stations, together with methods for separating these factors.

At the Alabama station methods have been improved for separating the antineuritic vitamin (vitamin F or B–P) from the antipellagric (vitamin G or P–P) and an elaborate study has been made of the pathology of experimental pellagra produced in rats by a deficiency of the latter vitamin. On a basal vitamin G-free ration young rats make little or no increase in weight, although they show no particular symptoms for from 2 to 4 weeks after a preliminary depletion period of 2 weeks. The animals then become somewhat emaciated, the hair begins to come out, an ophthalmia originating as a mild conjunctivitis appears, and in most cases there develops a dermatitis of wet or dry type. The feet become dry and scaly, and an arthritis frequently develops. The whole combination of symptoms does not appear in every animal, and the survival period may vary from 8 to 18 weeks from the end of the preliminary period.

The most striking internal condition is a gastroenteritis, which may involve the entire digestive tract. Pathological examination of the lesions has revealed the invariable presence of a Gram-positive coccus which is not pathogenic under ordinary conditions but which, when fed in massive doses, produces the characteristic pellagra-like lesions readily in about 80 to 85 per cent of the test animals and eventually in all cases. Concentrates of the preventive factor have proved effective in prophylactic and curative tests and have been found to inhibit the growth of the causative organism in culture media.

From these findings the theory is advanced that rat pellagra is an infectious disease which develops in the absence of a sufficient quantity of the protective factor, but is incapable of developing in the presence of an abundance of this factor. The quantity required for protection is thought to depend to some extent on the number and virulence of the organisms present and the age and individual susceptibility of the animal. Young animals are much less susceptible than older ones. Although it has generally been considered that the pellagra-preventive vitamin and the heat-stable factor vitamin G are identical, the most recent work at the Alabama station has shown that the correlation is not always good between protection against the infection and growth. The possibility that two factors are involved is receiving further study. Wheat and corn have been demonstrated by the Ohio station to be relatively rich in vitamin F and deficient in vitamin G and whole milk to be rich in vitamin G and deficient in F.

Some evidence has been obtained by the Missouri station that prolonged irradiation with a mercury vapor arc destroys vitamin G but not vitamin F as present in yeast and yeast concentrates. Confirmation of this observation should provide a convenient means for obtaining each of these factors free from the other, since autoclaving is known to destroy vitamin F but not vitamin G. The difficulty encountered in separating the two factors has prevented most laboratories from attempting to determine the relative distribution of these vitamins in food materials and has led to a continuation of work in undifferentiated B. The principal current value of this work consists in indicating what materials contain both vitamins F and G in suitable quantities, since a marked deficiency in either vitamin prevents satisfactory growth even though the other be present in abundance. With pellagra still constituting a problem in the Southern States, there is need for much more work along the lines of the investigation under way at the Alabama station and for extending rapidly information on the distribution of the antipellagric vitamin in food materials.

Inorganic elements in nutrition.—The discovery at the Wisconsin station, recorded in the previous report, that the ash of such materials as lettuce and cabbage is an effective supplement to iron salts in the cure of nutritional anemia in rabbits has been confirmed with rats, and the phenomenon has been explained by the discovery that copper in minute quantities can likewise supplement iron in the regeneration of hemoglobin. This is thought to point to the necessity of copper for the effective utilization of iron in hemoglobin building. The discovery has been hailed as significant in throwing light upon many puzzling problems on the utilization of different sources of iron, in suggesting that other inorganic elements existing in traces in food materials may be of greater significance than hitherto supposed, and in indicating that the whole problem of nutritive essentials has not been solved by the discovery of vitamins.

A mutual relationship between specific vitamins and certain mineral elements has been considered for some time at the Kentucky station, and the West Virginia station has suggested recently that some so-called vitamin effects are in fact due to inorganic elements. Such hypotheses require a large amount of experimental work for verification, with a refinement of analytical methods to enable the detection of minute quantities of these elements.

Recent studies at the Wisconsin station showed marked differences in the content of iron and manganese in different common food materials. The values reported for iron ranged from 0.00015 per cent for lemon juice to 0.0192 per cent for parsley. The iron content of the same materials grown in different places was shown to vary widely. Similar differences were observed in work going on at the Mississippi station. The manganese content of vegetables analyzed at the Wisconsin station ranged from 0.000074 per cent for rutabagas to 0.00079 per cent for spinach. The Massachusetts station recently found that cranberries from cranberry bogs along the coast are comparatively high in their iodine content—values from 26 to 3 parts per million being reported.

Food-consumption studies.—Two food-consumption studies have been made at the Mississippi station by the inventory method, one among the white people of two different soil areas and the other among negro tenants in the Yazoo-Mississippi Delta. The soil areas selected in the first study were the so-called brown loam and the shortleaf pine areas, in both of which cotton and corn are grown extensively. The brown loam area, which is the more fertile of the two regions, is noted especially for truck crops.

The dietaries of the families in the shortleaf pine area were found to be slightly less satisfactory in most respects than those in the more fertile section. Compared with the established standards, the diets even in the better section furnished only slightly more than the minimum requirement of calories, protein, calcium, and phosphorus and were markedly deficient in iron. The milk supply was generous, but the consumption of meat, of whole-grain cereals, and of fruits and vegetables was very low. The estimated money values of the food consumed varied from 19 to 56 cents per man per day and averaged 38.13 cents for the brown loam area and 33.78 cents for the shortleaf pine area. The amounts of food furnished by the farm averaged 69.78 per cent of the total in the brown loam area and 77.66 per cent in the shortleaf pine area.

In the study conducted among negroes in the Yazoo Mississippi Delta, the dietaries were found to be 10 per cent or more below standard in protein, calcium, phosphorus, and iron in over 50 per cent of the 80 families studied. The dietaries from the cash-settlement type of plantation were somewhat more adequate than those from the supply-settlement or the part-cash and part-supply settlement type. The average money value per man per day for all the dietaries was 21 cents, 44 per cent of which was furnished by the farm. The menus submitted showed that not only poverty but ignorance of proper food combinations was a factor contributing to the unsatisfactoriness of the diets. The findings are thought to explain to a certain extent the high incidence of infectious and contagious diseases and the high death rate among the negroes in Mississippi. Education in proper food habits and the attainment of these through better gardens and more chickens and cows is recommended as imperative for bettering the physical and economic condition of the negro in the State.

Preliminary reports by the Georgia station on a dietary survey of 100 white families in different parts of Georgia have indicated that the diets

are deficient in phosphorous, very deficient in iron, and less deficient in calcium.

Cow's milk for infant feeding.—The curd test developed at the Utah station for testing the suitability of milk for infant feeding has been applied to individual samples of milk from the university herd and to herd and individual samples throughout the State. In general, the tests have shown that the curd character of the milk is an individual characteristic of the cow rather than a breed characteristic, although there is a greater probability of finding cows giving a soft curd milk in some breeds than in others. Milk with low curd tension has been used for hospital infant feeding with beneficial results.

Sybil L. Smith.

AGRICULTURAL ENGINEERING

Systematic reorganization of a considerable proportion of the investigations in agricultural engineering at the experiment stations took place during the year, which appears to have resulted in the replacement in a large measure of superficial and unproductive endeavor by sound undertakings having practical agricultural end points. There were 268 active projects in the subject at 40 stations, and progress was made especially in the development of mechanical equipment, farm structures, and land-reclamation practices along practical and economical lines, and in the application of electricity to agricultural practices.

MECHANICAL EQUIPMENT

The productive work in mechanical equipment during the year was concerned especially with the basic improvement of machines to perform certain necessary operations better and more economically.

Traction machinery.—The difficulty encountered in adapting available traction machinery to agricultural practices, owing to the severe and special requirements imposed by the latter under certain conditions, prompted investigations into the principles and requirements of agricultural draft and traction, which resulted in several significant achievements by the stations. For example, the Alabama station established a correlation between laboratory findings relating to the principles of traction in soils and field results obtained with tractors engaged in the performance of agricultural operations. This accomplishment made it possible to design tractor wheels and lug equipment adapted specifically to give maximum tractive efficiency under the individual soil conditions so far tested.

As the result of investigations of draft requirements the Pennsylvania station found that a considerable saving in time and energy could be effected by the use of spring release hitches when plowing with tractors in rocky soils, and the California station established the utility of a properly selected drawbar spring which gives satisfactory and constant protection to the drawn implement at low and medium speeds. This observation applies particularly to cases where the implement can withstand a drawbar pull of from one and one-half to two times the maximum tractive ability of the tractor. These findings and the results of other studies by the California station on the dynamics of tractors and of the hitches between tractor and implement and their alignment contributed materially to the stability, safety, economy, and effectiveness of the use of mechanical traction in farm draft operations.

Internal-combustion engine fuels.—The development of cheap and efficient fuels for farm gas engines, a problem of considerable economic importance, was given attention by the stations for some time, and definite progress toward its solution was made during the year. The California station, for example, found that most farm gas engines now on the American market, which are designed to operate on gasoline or kerosene, can be operated with mixtures of either kerosene or gasoline with alcohol without structural changes and with an increased economy in fuel consumption, easy starting, lowered carbon deposition, and lowered oil dilution. This held true with a mixture ratio as low as 1 part of gasoline to 10 parts of 190-proof alcohol, thus demonstrating the possibility of improved as well as more economical operation by the use of blended fuels of this character.

Tillage machinery.—Studies of soil dynamics as it relates to tillage promise to reduce the high cost of tillage in the production of major crops, due to the large consumption of power and labor. Progress in this work is indicated by the finding at the Alabama station, for example, that the scouring properties of plow metals can be varied and largely controlled by heat

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treatment. In fact rapid cooling of ordinary plow metal in mercury was found to result in the lowest adhesion of soil to the metal surface. In a similar manner the California station also showed that heat treatment to the greatest degree of hardness possible tended to better maintain the sharp-cutting edges of pearlitic manganese steel disks in gravelly soils than did heat treatment to lower degrees of hardness of the same metals, or nonheat treatment of common crucible steel disks.

Such evidence presents the very practical suggestion that tillage tools which wear the least scour the best, and vice versa. It also points the way, by the proper use of the principles of alloying and heat treating, toward the development of tillage-tool metals adapted to particular soils and soil conditions. These metals, when used in tillage operations, should interpose a minimum of resistance to the passage of soil over the tool surfaces, thereby materially lowering the amount of draft power required and decreasing the maintenance cost of the tools themselves.

Harvesting and threshing machinery.—The demand for economy in the consumption of power and labor in the harvesting and threshing of grain and large-seeded legumes has been the incentive for experiments which have been productive of information of practical worth. For example, the Pennsylvania station effected a considerable saving in the cost of harvesting and threshing wheat and oats by the use of the combine method so long as the straw was left in the field, under which conditions a smaller total amount of labor was required. However, where the straw was removed it was cheaper to use the binder and to thresh separately.

While this and other defects of the combine method have become evident, the potential economy of the method has pointed to the importance of studies of combining requirements to provide a basis for the correction of these defects. In this regard the Virginia station determined the nature of certain fundamental improvements required in combine construction and operation for the harvesting of soybeans, it being established, for example, that a cylinder speed of from 2,300 to 2,500 feet per minute is necessary for soybeans grown in Virginia, and an increase in separator speed of from 8 to 10 per cent is desirable. These findings, together with those at the Illinois station on the mechanical advantage of the lower cutting of soybeans and those at the California station on the economy of bulk handling of combined grain, constituted evidence of distinct progress in the development of combine-harvesting methods and equipment along definite cost-saving lines.

Crop-drying equipment.—The high cost of production of crops requires that crops be of superior quality regardless of the conditions under which they were matured and harvested. Definite success was reported in the artificial drying and curing of corn at the Wisconsin and Illinois stations, of hay at the Indiana station, and of fruit, vegetables, and nuts at the California and Oregon stations. In the Middle West, for example, where corn is perhaps the biggest money crop, the Illinois station established that a drying temperature of 130° F. does not lower the germination percentage of corn, and that corn for livestock-feeding purposes can be dried at a temperature as high as 150°. These findings resulted in the development of practical equipment for this purpose.

Feed-grinding machinery.—The stations have secured abundant evidence that the grinding of certain feeds is often desirable, particularly for hogs and dairy stock, and the degrees of fineness of grinding for certain purposes are being established rather definitely. Since considerable power is consumed in feed grinding, economy in this respect is important. Among others the Wisconsin station, for example, in establishing the utility of the hammer mill for feed grinding, has found that for each set of conditions there is a critical point in the quantity of unground material fed a hammer mill at which the mill is most efficient. Such observations are providing the basis for the development of grinding equipment and its operation which should produce feed, ground to desired degrees of fineness, at a minimum cost for labor and power.

Solar water-heating equipment. — The heating of water has been found to be the most expensive feature of home cooking and one of the more expensive features of the dairy industry, and the efforts of some of the stations to develop cheaper and more efficient water-heating methods have been quite successful. The Alabama station, for example, has established the fact that solar energy may be effectively employed on a small scale for this pur-

pose, and has developed equipment which produces temperatures in water ranging from 90° to 150° F. during August, September, and October, and provides sufficient hot water for the use of a dairy of 30 cows.

STRUCTURES

The productive work in structures at the stations was based largely on the premise that housing conditions which control temperature, air movement and supply, and humidity are important factors in the profitableness of the animal, dairy, and poultry industries and in the proper storage of fruit, vegetables, and other crops. Household sanitation also received some attention.

Poultry structures.—Recognizing that the proper housing of poultry is essential for maximum economic production, several of the stations have been investigating housing requirements under controlled conditions and in some instances have obtained noteworthy results. The Iowa station, for example, has shown that air purity in the poultry house is not a factor of such importance in the health and productiveness of poultry as are temperature and rates of air movement. The development and experimental use of automatic temperature and humidity regulators has made possible considerable progress in specifying the necessary ventilation and temperature conditions in poultry houses and in expressing them quantitatively for practical use.

The Nebraska and California stations also established certain relations between lighting in poultry houses and maximum production, and the Washington station developed mechanical ventilation in poultry houses involving the practical use of artificially heated air.

Dairy structures.—The recognition of the necessity for proper ventilation of dairy stables as an important factor in economical maximum-quality production was responsible for some practical results. At the New York Cornell station, for example, where a special chemical technic has been developed for studying the direction and relative velocities of air currents in stables, the utility of maintaining a heat reservoir by the use of floor outtakes was demonstrated as a practical means of securing temperature control in stables. The stimulation of convection currents by locating air intakes on the side walls was found to prevent the accumulation of moisture on walls and ceilings, and the introduction of from 50 to 60 cubic feet of fresh air per minute per head of stock was established as sufficient to ventilate adequately and maintain a sweet, dry stable. The above and similar findings, such as the establishment at the Iowa station of a relation between the quality of milk produced and the temperature inside and outside of the dairy stable, are suggesting the lines along which the practical control of the atmospheric conditions in dairy stables should proceed.

Crop storages.—In the storage of fruits and vegetables, culinary and nutritive qualities as well as keeping qualities must be taken into consideration, and the evidence now available points to the necessity of giving each variety of fruit or vegetable individual treatment in this respect. Among the examples of definite progress in this line of study may be cited the findings of the Massachusetts station, which clearly established the inferiority of common storages for apples, and the evidence obtained at the Massachusetts and Indiana stations of the practical value and economy of different degrees of cold storage in the fall of the year for certain varieties of apples. The Georgia station also found that certain structural changes in sweet-potato storage houses, such as shortened draft ducts, sloping ceilings, and heat distribution by pipes, which produce more effective evaporation and more uniform temperature and relative humidity conditions, are of fundamental utility in securing higher quality in sweet potatoes at a lower cost.

Farm sewage disposal.—The attainment of greater comfort and sanitation in the farm home at a minimum cost was facilitated greatly by the results of studies of farm sewage-disposal systems at the Illinois and Montana stations. The findings at the Illinois station, in particular, gave definite information in regard to the size, shape, arrangement, and manner of operation of sewage-disposal plants best suited to farm families of different sizes and to different farm-home conditions.

LAND RECLAMATION

The productive work in land reclamation during the year has been based largely upon a growing appreciation of the necessity for maximum economy and efficiency in the methods and permanency in the structures and equipment used in irrigation and

drainage practices and in land clearing.

Irrigation.—The time-honored duty-of-water tests at the stations, to provide bases for irrigation practices, appear to be giving way gradually to more fundamental investigations designed to introduce greater effectiveness, precision, and economy in the handling and application of irrigation water to crops. For example, controlled studies at the Idaho station gave information making possible the correlation of the infiltration and movement of irrigation water in soils with their porosity, thus aiding materially in the more effective and economical use of water, particularly in soils with physical and mechanical properties more or less adversely influenced by alkali.

The Colorado station also made progress in determining certain of the principles governing the loss of irrigation water from different soil types at different altitudes which should aid in the better control of such losses, and also practically completed the development of the Venturi flume which, under proper conditions, materially increases the accuracy of irrigation-water measurement.

Drainage.—An improved conception of the problems involved in the practical development of land drainage was apparent in the studies in progress at the stations. The California station found that, contrary to the general opinion, the water table in the soil between lines of tile is practically level except within a very short distance of the tile, and the depth of the tile or their spacing does not materially alter the shape of the water table. This would indicate that the major part of the lateral adjustment of soil water due to the removal of some of it by a drain takes place below the flow line, and that in the portion above the flow line the movement is largely vertical. Such clearer conceptions of what takes place in soils under drainage should aid materially in efforts to increase the effectiveness and economy of the practice.

The Michigan station also demonstrated the utility of mole drainage of soils under certain conditions and made progress in developing the necessary equipment and method of procedure along practical and economical lines.

Land clearing.—As examples of the progress made in land-clearing investigations may be cited the finding of the Pennsylvania station which definitely showed the utility and economy of drilling and blasting in the clearing of land of limestone rocks, and the observation of the California station in regard to the greater economy in stump removal of blasting and burning in the barrel-type stove than of pulling or blasting alone.

USE OF ELECTRICITY IN AGRICULTURE

The part taken by the stations in the national movement toward the use of electricity in agricultural practices has been restricted largely to certain definite lines, such as the use of electricity in certain dairy industry processes, in refrigeration, in poultry husbandry processes, in stationary mechanical operations, and in the household.

Dairy utensil sterilizers.—Cheap and effective sterilization of dairy utensils, recognized as an important problem, received considerable attention looking toward its solution, especially at the Alabama and California stations. At both stations the utility and economy of electricity for this purpose was demonstrated and practical equipment and methods for its proper use were developed.

Electric refrigeration.—The refrigeration of farm products to insure quality has become more or less of a necessity and the effort to develop efficient processes has constituted an interesting and profitable phase of investigation at the stations. The New Hampshire and California stations demonstrated the utility, ease of control, and economy of certain refrigeration processes using electricity as the source of energy. The former station established the fact that the main economic advantage of the electrical method over the use of ice is the almost entire elimination of labor.

Electric brooding.—Where the poultry industry is a major commercial enterprise the stations are recognizing that cheap and efficient processes for the satisfactory brooding of young chicks are of considerable importance in the success of the undertaking. The Oregon and California stations, for example, have not only established the superiority in several respects of electric brooders over other types but, from investigations of the electric types themselves, have made considerable progress in determining the principles governing the most efficient electric brooding, which can be translated into terms of usable equipment.

Use of electricity in mechanical operations.—Flexibility, ease of control, and saving of labor are qualities of electricity which favor its use in mechanical farm operations. Work at the Oregon and Washington stations on electric hay hoisting, at the Wisconsin, Iowa, and Oregon stations on electric feed grinding, and at the Indiana and Wisconsin stations on electric silage cutting and elevating are examples of the performance of mechanical operations at a maximum of economy in time and labor by the proper use of electricity. In silage cutting especially the process has been developed to the point at which as little as 5 horsepower is required for the work. Such investigations are leading toward maximum convenience as well as economy in the performance of the mechanical duties of the farmyard.

Robert W. Trullinger.

AGRICULTURAL ECONOMICS AND RURAL SOCIOLOGY

Station work in agricultural economics and rural sociology under the Purnell Act has been in progress three years and is growing rapidly under the stimulus of public demand. Of the 551 projects reported as active in this field in 1927–28, 321 or 58 per cent were Purnell projects.

The results of new work now are being published. During the past fiscal year the office received more than 100 station bulletins and a number of circulars on various phases of agricultural economics and rural sociology. A review of the publications indicates what appear to be the general tendencies in research in these fields. This article is based on such a review.

In attempting to appraise the aims, ideals, and scientific motives in research in agricultural economics it is necessary to take into account the conditions that have prevailed in recent years, in which economic problems of agriculture have been the object of an unusual degree of public interest and the result an unprecedented demand for investigations designed to yield results quickly and of immediate applicability. While the importance of endeavoring to meet the wishes of the public which has provided so generously for the support of research is recognized, it is desirable to bear in mind the dangers of excessive haste resulting in poorly planned investigations and in reports that are fragmentary, sketchy, and too hastily thought out to yield the results contemplated.

A review of the bulletins received in the last year indicates an effort to meet the public demand for results of ready applicability, and, while many publications suggest an impatient haste to "get into print," the general trend in research standards is decidedly encouraging. A considerable number of reports are little more than compilations of miscellaneous information, with few conclusions drawn therefrom; the majority of the reports are of a stronger type.

Results to date appear to substantiate the point of view (held by this office and shared in by many directors and by leading research specialists) that a project will give the best result if confined to a definite and manageable problem rather than if extended over a general field of study. Those studies which have been confined to specific topics as a rule have yielded information upon significant relationships, a knowledge of which should be far more helpful in improving the economic status of agriculture than studies in which attempts have been made to cover a broad field in one general state-wide survey, resulting in miscellaneous and ill-digested data. That the reports which have appeared in the last year indicate improvement in research work in several directions may be explained best by a brief review of the major phase of the investigation in this field.

FARM MANAGEMENT

Studies in farm management, including cost of production and "trade-area" investigations have yielded in the past year the largest number of reports of any branch in agricultural economics, 46 bulletins on these subjects having been received. The principal aim of these studies has been to obtain information to aid in the adjustment of production to changing economic conditions.

Because of the complex nature of the more general projects, it appears to have been difficult in many instances to ascertain fundamental relationships. Here, again, in those studies where specific phases of agricultural adjustment were outlined as separate and distinct projects, the results have been more definite and probably will be more helpful. It should be noted in passing that the plea for definiteness in research should not be construed as an unqualified criticism of the general studies, many of which serve a useful purpose, especially in

localities where little or no preliminary work has been done and where these investigations serve not only to direct public attention to the general and perhaps the more outstanding problems but also to aid in selecting the specific phases for more intensive study.

In some of the farm-management studies a promising beginning has been made toward developing standard plans for more profitable combinations of crop and livestock enterprises in the communities studied, thus going beyond the mere description of existing farm practice.

Costs of production.—Cost-of-production studies based on detail cost routes or on intensive surveys in selected areas in many cases are yielding information on physical requirements in production and relative profitableness of different combinations of enterprises with respect to prevailing prices and costs. There is evidence of greatly improved statistical method in several of these reports, although it should be noted that others are conspicuously weak in this respect. There is, however, evidence of progress in method of analysis, and these investigations afford additional illustrations of the fact that research yields better results when carried out on a definite topic and within a sufficiently limited scope to permit a more detailed analysis.

The importance of improved efficiency of farm operations as such has not been overlooked, although the dominant note in farm-management research has been to aid in the adjustment of farming to meet changing price relationships. A greater number of reports have appeared on enterprise studies; that is, studies of particular phases of farming, as, for instance, the place of beef cattle, hogs, poultry, or of potatoes, corn, etc., in the farm business of different localities. Enterprise studies of this general type comprised 28 of the 46 bulletins on farm management and closely allied subjects within the last year.

Outlook investigations, i. e., studies of the probable trend of prices of the commodities referred to, have formed the basis for a number of bulletins and circulars. Data on costs of labor and material, on soil and climatic conditions, etc., are included and comparisons made with other areas. Studies of this kind, while generally well received, are admittedly experimental. Their reliability depends on the degree of certainty with which future trends of supply and demand can be predicted. There is admittedly a great deal of room in this field for statistical research of a fundamental character without which periodic reports on supply and demand may be characterized as current services and not as research.

General surveys.—A number of the bulletins issued report general and indefinite studies on the economic aspect or situation of some phases of farming or of agriculture in general in the State. As a rule, these studies suggest the inadvisability of attempting such all-inclusive investigation. However, it should not be assumed that all of these investigations are of little or no value.

In some of the general studies the investigator is well aware of the preliminary character of this work and conscious of the limitations as well as of the possibilities of his data. Effort has been made to show not only the place of certain major crops and classes of livestock in the farm organization of an area in which fairly uniform conditions prevail, but also to connect general farm-management problems with changing factors affecting supply of and demand for the commodity as a whole. For instance, reports giving the status of the apple industry have shown not only how apple orcharding fits into the general scheme of farming in some localities but have also given data on the number of nonbearing trees, and other factors suggesting to the producer the trend that may be expected in the supply of the commodity and thereby giving him a basis for judging the competition which he as an individual farmer may have to face.

Studies of types-of-farming areas.—The term "types-of-farming areas" depicts a type of farm-management study which is now coming into vogue but which in the past year has resulted in only one or two station bulletins. It is an effort to ascertain by general survey and compilation of existing data, the prevailing type of farming and to map the type areas thus ascertained. The data are obtained by farm-to-farm surveys and compiled from climatological records, soil surveys, and more recently from census schedules.

Studies of this character are largely descriptive and admittedly preliminary to more specific investigations to ascertain fundamental facts and relation-

ships designed to aid farmers in each type-of-farming area to adjust their operations to meet more effectively present and prospective forces of competition and to increase returns through more efficient operation. Upon completing the preliminary phase, it is proposed to conduct more intensive studies on a limited number of farms, the results of which it is thought should be applicable to the type-of-farming area within which the intensive study is made.

The aim of this program is commendable and should yield good results if carried out with care and with the recognition that the making of a map showing types of farming by itself is description, and that the second phase—the intensive study—is the real research feature of the program.

Trade-area studies.—One type of study perhaps less popular at present than a few years ago is the so-called trade-area investigation, in which the investigator seeks to ascertain the market opportunity in a given city for the products produced in the surrounding farm community. Data have been secured on the consumption of various products in the urban center and the amount of these products obtained from distant places. The possibility of producing on the near-by farms the products shipped in is ascertained by farm-management studies in which information is sought on the possibility of increasing the production of certain products on these farms with profit to the farmers.

Price studies.—Studies in prices of farm products have yielded a number of publications in the last year. While some of these are little more than a catalogue or series of price data, many of the reports bear evidence of careful application of statistical technic to price problems. This should be encouraged, even when the result is not obviously applicable in the immediate future. In economics, as in other lines of investigation, theoretical knowledge or fundamental principles precedes applied knowledge, although this sequence may not always be as clear as in some other fields.

In advanced research in prices the investigator necessarily proceeds on the basis of some hypothesis as to the relation of price factors, and endeavors to test the hypothesis by applying the technic of statistical research to data at hand. Studies in the elasticity of supply, i. e., in the effect of prices of farm products and of cost factors upon the quantity produced, have come into considerable prominence in recent years as a part of the general approach to problems of agricultural adjustment.

OUTLOOK STUDIES

As a product of statistical studies by the stations and by the United States Department of Agriculture, a number of States publish reports periodically on the outlook for agriculture in the State, suggestive of probably advantageous adjustment in the production program of farmers. These publications are of an extension character and are designed not to outline a specific program but to present clearly and briefly the more essential facts on which the individual farmer may base his actions in production and marketing.

These outlook studies are admittedly in the experimental stage, but their growing prominence has come as a result of popular demand for information to enable the farmer to plan for the future more effectively than would be possible without such information. The importance of fundamental research as a basis for such reports is obvious, although the current compilation of price data alone and without fundamental analysis should not be designated as research.

MARKETING

Marketing, next to farm management, was the subject of the largest number of research reports in the past year—28 station bulletins and 2 circulars. While some of these reports deal with marketing in general in a sketchy manner, the majority of them approach the problem of marketing from the standpoint of specific commodities. This is indicative of a trend toward more definite studies. Moreover, the field of commodity marketing is being subdivided for detailed study of specific problems.

While some of the recent bulletins on cooperative marketing are merely the result of elementary and general surveys of existing practices in many or all phases of cooperation in a State, there is evidence of a more fundamental purpose in which each study is confined to definite problems of business organization, management, membership, etc., in cooperative marketing. This tendency has been stimulated by leaders in the stations and in the United States Department of Agriculture.

FARM TAXATION

Farm taxation has become increasingly important as a field of station research in recent years. At the close of the last year, (1927–28), there were 21 active projects reported to this office, 13 of these being under the Purnell fund. The reports published to date on the whole have been very well received, for they have thrown a great deal of light on the farmer's tax problems. These studies have included assessment of farm property, analysis of the amount of taxes paid by farmers in relation to property value and to income, comparisons with taxes paid in cities and villages, etc. Increasing attention is being given the expenditure of funds collected by taxation.

It is important to note that more and more effort is being made to concentrate the investigations on selected areas in an effort to secure more detailed information. This should be of distinct value to tax administrators and should contribute to improvement of public policy in State and local expenditures and taxation.

Investigations on various aspects of rural life were reported in 11 station bulletins and 2 circulars in the past year. Research in this field is probably more difficult than in most other fields because it lends itself less to definite quantitative study. Consequently some of the bulletins are little more than compilations of miscellaneous material, much of which could have been written on the basis of existing material and without the investigations proposed in the project outline. Despite these difficulties, several bulletins show notable progress in research procedure and technic and are indicative of successful effort toward a more tangible approach to research problems. In many instances the field has been divided into definite research topics that lend themselves to systematic study.

GENERAL IMPRESSIONS

Although the station bulletins received in the last year bear evidence of progress and give ground for an optimistic outlook for research in agricultural economics and rural sociology, there is also evidence here and there of deficiencies that are tangible and important enough to warrant special effort to overcome them.

The suggestion often made that research projects should be planned with care deserves repetition. Too frequently projects are launched with a quite indefinite or immature purpose and the printed results contain evidence that early accomplishment was the dominant aim. Directors and individual workers, who maintain contact with practical farm problems in their immediate locality and who are advised of the broader needs of agriculture in general, surely could not fail to have before them many specific and worth-while subjects which, if their importance and research possibilities were evaluated, would constitute a list of definite topics from which selection could be made, suited alike to the more immediate needs and to the available funds and personnel.

This criticism is by no means generally applicable, but project outlines and research reports received in the past year indicate that it is sufficiently pertinent to warrant mention. The spirit of public demand in recent years for immediate results should not prevent careful preparation of projects, and a proper interpretation of the spirit of that demand should lead to thorough planning and execution of the investigation; for the public wants not printed matter hastily compiled but reliably digested results that can be safely applied in the improvement of agriculture and rural life.

In planning his investigation every project leader should acquaint himself with at least the principal results of previous studies in the field of his project. With such preparation projects are more likely to yield new and pertinent information. A number of current revisions and bibliographies are conveniently available for the use of research workers and other interested persons. The Bureau of Agricultural Economics has published in the past three years no less than 25 extensive agricultural-economics bibliographies which should be of special assistance to workers in this field.

Despite the able administration of research in the stations in general, it is evident that in some cases more critical judgment should have been exercised in projecting research and in approving manuscripts for publication. Manuscripts based on inadequate data or on obviously faulty analysis contribute little to knowledge and may even be misleading.

While recent publications bear evidence of improvement in the use of statistical technic in general, many bulletins are obviously weak in this respect. With the growth of station work in economics it might be pos-

sible, in an increasing number of stations, to add to the staff someone having more than the usual amount of knowledge of economic statistics who would be available for consultation with other workers. This should aid greatly in strengthening the work and in preventing the appearance of publications until the data are analyzed sufficiently well to inspire confidence and to give reliability to the conclusions.

The importance of improved statistical technic is illustrated in many of the bulletins received in the past year, especially in those which are the results of cooperative studies by the stations and by the Department of Agriculture, whose specialists have aided in the statistical analysis. Bulletins prepared and issued by the stations independent of any other agency are not to be thought of as inferior in every case; but it is true, nevertheless, that the bulletins prepared cooperatively are, as a whole, superior from the standpoint of technic of analysis.

In conclusion, it may be said that while the results of economic research in the stations in recent years are gratifying, there is also abundant evidence of room for improvement. Moreover, there is reason to believe that since we are entering into what may be called more normal times, increased definiteness should characterize research policy, looking toward fundamental and perhaps increasingly permanent results. In addition to a necessary amount of research on immediate and relatively transitory problems in economics, there should be increased effort to conduct studies aiming to reveal underlying principles and fundamental relations.

Eric Englund.

SOME RECENT DEVELOPMENTS IN AGRICULTURAL RESEARCH IN THE BRITISH EMPIRE

One of the outstanding developments in agricultural research during the period covered by the present report has been the increased attention which has been given to its upbuilding in the British Empire. This movement has been sponsored quite frankly as a phase of imperial policy and, as would be expected, its appeal for governmental support has been less to altruism than to an enlightened self-interest. Nevertheless the truism that science knows no national boundaries carries with it a clear implication that progress in research by any nation is a matter of concern to all the peoples of the earth, and from this standpoint the material strengthening of agricultural-research agencies which seems likely to ensue is a matter of world-wide interest and significance.

Much of the initiative for the recent developments may be accredited to the Empire Marketing Board. This board was appointed in May, 1926, upon the recommendation of the Imperial Economic Committee, an official body organized during the postwar years to foster the development of the British Empire as an economic entity. Much of the board's membership was drawn from the committee itself, and the chairman of the board is the Secretary of State for Dominion Affairs and for the Colonies. A parliamentary grant of 500,000 pounds for the first few months and 1,000,000 pounds per year thereafter was made available immediately, and without statutory limitation aside from a general direction to employ these amounts in "furthering the marketing of Empire produce" in Great Britain.

The board early decided upon the utilization of a considerable proportion of its funds in research. It was felt that if its efforts were to be permanently effective it must do much more than undertake an intensive advertising campaign based on patriotic appeal. "It is no good telling the public to buy Empire produce," the board reasoned, "unless it is obtainable in the shops, good in quality, and reasonable in price. . . . The best service that can be done to the Empire producer is to place freely at his disposal the resources of science and economic investigation—to see that he is made aware of the latest methods of sowing and planting, of tending and harvesting; to show him how his produce should be graded and packed to insure that it is transported safely and without deterioration; to suggest lastly how its presentation, in the shop window or on the counter, may be fitted to win the housewife's critical eye."

The work of the board was thereupon subdivided into scientific research, economic investigations, and publicity. As regards research, it made no attempt to engage in such work directly, as its function was visualized from the outset to be that of "fortifying existing scientific institutions in such measure as would enable them to intensify or develop their work, and of making possible the establishment of new institutions to meet new and proven needs."

The fundamental necessity for increased scientific research in the Empire was acknowledged without qualification, and the board has felt that in the vigorous support of scientific research it has "an evident duty and a notable opportunity." As a result of its survey of the situation, the board declared that "it is plain that the results of even proved agricultural research have as yet found but a very imperfect reflection in the practical agriculture of the Empire. It is plain that Empire development, and therefore Empire marketing, postulate the examination of a wide and diverse range of problems, many of which have not, so far, been subjected to scientific examination at all. It is plain that Empire expenditure on agricultural scientific research and the dissemination of its results still falls short not merely of Empire requirements but of the scale attained by at least one other nation with lesser responsibilities."

During the period from July, 1926, to May, 1928, the board approved allotments of well over 1,000,000 pounds for research projects and institutions. Many of these grants are to be distributed over a period as long as five years, but by March 31, 1928, actual expenditures had been made of 112,784 pounds. In a number of instances, the grants were made contingent upon the raising of supplementary funds from other sources, and those thus far reported have totaled on a 5-year basis 871,086 pounds.

In its allotment of funds the board has endeavored to regard as its prime function the furtherance of basic research, applicable sometimes to the whole of the Empire but always to more than one of its countries. "It has deliberately chosen the part of sustaining scientific enterprises whose wide bearing or distant range removed them from the scope of any single Empire government." Many of the initial appropriations have been made to scientific institutions in Great Britain, where, broadly speaking, scientific work of general interest is at present more fully developed as well as more accessible for the board's scrutiny, but the ultimate aim is to increase the relative allotments to overseas institutions as their facilities increase and closer contacts are forthcoming.

One of the major projects which the board is fostering is the development of a chain of tropical and subtropical central research stations. Assistance has already been granted to the Imperial College of Tropical Agriculture at Trinidad, where an allotment of 21,000 pounds for capital expenditure will be matched by a like amount contributed by the Empire Cotton Growing Corporation and where 8,000 pounds in addition has been allotted for maintenance. It has also appropriated 6,000 pounds for three years toward the cost of maintenance of the Amani Institute in Tanganyika Territory, an institution originally founded by the Germans during their occupancy of the region and now being restored in part by contributions by the Governments of several East African dependencies. A third grant of 25,000 pounds for capital expenditure and 5,000 pounds additional per annum for five years has been made to establish a tropical-research station in Queensland in duplication of a similar appropriation by the Commonwealth of Australia. As a fourth member of the chain, the Government of the Union of South Africa has tendered the services of its Veterinary Research Station at Onderstepoort, and it is expected that eventually other institutions will be added.

Another important undertaking which is still under consideration looks toward the better organization of the colonial agricultural services. A committee headed by Lord Lovat, Parliamentary Secretary for the Dominions, recommended in March, 1928, the appointment of a colonial advisory council of agriculture and animal health and the formation of a colonial agricultural service. The council would coordinate agricultural research in what are termed the nonself-governing dependencies, while the colonial agricultural service would include a specialist wing for research and an agricultural wing for administrative work. The Empire Marketing Board has allotted 22,000 pounds per annum for five years to this project, and it is expected that about five times this amount will be contributed by the colonial governments.

The allotments of the board for specific branches of research have covered a wide range of subjects. Prominent among these is the development of low-temperature research, for which a total of 164,500 pounds has been made available. The projects include the enlargement of a low-temperature research station at Cambridge, the erection of a new station at East Malling for cold-storage experiments with fruit on a semicommercial scale, and investigations of the refrigerated transportation of Irish Free State dairy

products. Still another grant has been approved for the establishment of a low-temperature research station at Trinidad, where the effects of cold storage on tropical fruits, especially the banana, are being taken up in informal cooperation with the Cambridge station.

Other horticultural studies are projected under grants to the East Malling, Long Ashton, and Cheshunt research stations for the extension of their work, and the establishment in cooperation with the Government of Sierra Leone of an experimental fruit farm for ascertaining the cost of growing and shipping bananas and grapefruit. A small allotment has also been made to the Government of Fiji for use in the improvement of methods of cultivation, handling, drying, and grading of copra, and another has provided for studies in Trinidad looking toward the production of a variety of bananas immune to the banana disease.

The board has contributed 8,000 pounds toward the erection of a new building to house the Imperial Bureau of Mycology, 11,600 pounds for studies in Scotland of the virus diseases of potatoes, and 520 pounds for an investigation of the dry-rot disease of swedes and turnips by the Ministry of Agriculture and Fisheries. A grant of 800 pounds to the Rothamsted Experimental Station will permit of the erection of six so-called "Wisconsin" tanks whereby the temperature and humidity of the soil can be controlled. These will be used for studies of cotton diseases of special interest to growers in the Sudan.

In the field of entomology, three major projects have been authorized. These provide, respectively, 15,000 pounds capital for the establishment and 5,000 pounds per annum for five years for the maintenance of a laboratory in Buckinghamshire for breeding beneficial parasites, 20,000 pounds capital for the establishment of an institute of entomology at the University of Cambridge, and 30,000 pounds for the provision of adequate accommodations for the department of entomology at the Natural History Museum. Smaller amounts have also been made available for studies of the entomological control of noxious weeds at Cawthron Institute, New Zealand, and of the insects injurious to dried fruits and other stored products.

One of the most comprehensive projects under way is the pasture investigation. This project deals with the mineral content of natural pastures, with specific reference to deficiencies in the soil and their effect on the growth and strength of livestock. For this study 10,000 pounds has been allotted to the Rowett Research Institute of Aberdeen, 12,375 pounds to work in Australia, 4,000 pounds to New Zealand, and 10,000 pounds in Southern Rhodesia. With the exception of the work in Aberdeen, these amounts are duplicated by like sums from local sources, so that the total expenditure available on the project may be 62,750 pounds.

The Universities of Cambridge and Edinburgh have received allotments of 7,000 and 10,000 pounds, respectively, for animal-breeding work. The latter institution has also been given 25,000 pounds for research in cooperation with the British Association for the Woollen and Worsted Industries, on fundamental studies of sheep-breeding problems and the determination of effective standards for raw wool. Furthermore, there is a grant of 1,900 pounds for a study of stock-rearing problems in Palestine which has already revealed considerable improvements in calf-raising methods and has attracted much local attention.

In poultry research two projects have been approved, one of 19,500 pounds to the Rowett Institute for several studies and the other of 3,700 pounds to the Ontario Agricultural College for a study of quality in eggs and the effect of dietary factors on hatchability. The National Institute for Research in Dairying at Reading has received 3,200 pounds for studies of "red spot" in cheese and "fishiness" in dairy products, and the Board of Agriculture for Scotland, the Scottish Board of Health, and the Ministry of Home Affairs for Northern Ireland 7,760 pounds for an investigation of the utilization and marketing of dairy products, including the feeding of milk to school children.

Several other dietetic problems are receiving attention from the board. Two of these deal with vitamins, one at the Lister Institute on the vitamin content of fruits, vegetables, and dairy produce, for which 4,000 pounds per year is allotted for five years, and the other a study of the nature of the variations in the vitamin content of cod-liver oils, for which 3,000 pounds has been assigned. A third project takes up physiological and pathological conditions associated with certain rational

and specialized diets, and is being carried on at the Rowett Institute.

The economic investigations thus far center around the marketing methods in England and Wales, the Ministry of Agriculture and Fisheries having a grant of 40,000 pounds per annum for five years, which is being used in cooperation with several educational institutions. There are also available smaller grants for studies of egg marketing in Scotland, the marketing of Northern Ireland produce, cooperative marketing in Jamaica and elsewhere, and the export of pedigree stock and improved seeds. Much of this work is being supplemented by demonstrations.

One of the most important and far-reaching undertakings of the board has doubtless been its financing of the Imperial Agricultural Conference. This body was in session in London from October 4 to 28, 1927, and its meetings were followed by a tour of research institutions in England and Wales, Scotland, and Northern Ireland. About 200 delegates were in attendance, representing nearly every domain under the British flag, and with Lord Bledisloe, Parliamentary Secretary of the Ministry of Agriculture and Fisheries, as chairman. Originally suggested, it appears, by Sir John Russell, in 1925, this was the first conference of research workers for the entire Empire ever attempted, and a gathering of great value from the standpoint of both imperial solidarity and the promotion of agricultural research.

Among what may be described as the by-products of the conference were the numerous documents prepared for its sessions, many of which brought into readily available form information which had been widely scattered. Among this material was a review of the status of agricultural-research work in Great Britain and Northern Ireland, a similar review of work in the overseas Empire, abstracts of recent papers on agricultural research in Great Britain, and a list of agricultural research workers in the British Empire. Arrangements were made in the case of some of this information to secure hereafter its systematic compilation and issue.

Many matters of importance were considered by the conference, and in most cases formal recommendations were adopted. The conference indorsed the plan of the chain of central tropical and subtropical research stations previously referred to, and suggested that they should in the main confine themselves to long range and wide range research. It advocated the establishment of imperial clearing stations for soil science at Rothamsted, animal nutrition at the Rowett Research Institute, and animal health in London, and the formation on a smaller scale of correspondence centers for several other subjects. It gave much attention to problems associated with the recruitment and training of adequate personnel, and it made many detailed recommendations as to the development of specific subjects.

In most cases the recommendations of the conference involved the expenditure on a cooperative basis of funds to be supplied by the various constituent parts of the Empire, and authority was lacking for their representatives to make definite commitments of funds. Delay has therefore resulted in putting into effect many of the projects on which there was general agreement, and some pessimism has been expressed over the time required to make this large cooperative venture fully effective. As a means of remedying some of the difficulties, *Nature* has suggested that "the best means for insuring that no time will be lost between passing schemes for cooperative research and putting them into effect would be to create immediately a central fund, based upon contributions of each constituent part of the Empire, and large enough to permit of immediate action being taken by an Empire research council upon which the Dominions, India, and the Colonies are properly represented."

A second conference of similar scope has been arranged to meet in Australia in 1932, by which time it is hoped that substantial progress will have been made along the various lines projected. In the meantime, however, definite and tangible results are accruing from the large expenditures controlled by the Empire Marketing Board, and it is the prevailing feeling that in many more or less intangible ways the conference, as stated by its chairman at the closing session, has been "a great step forward with a view to the spread of ascertained knowledge to meet the needs of the Empire in relation to its most vital industry."

HOWARD LAWTON KNIGHT.

PUBLICATIONS OF THE STATIONS (1927-28)

The following is a list of regular publications of the stations received by the office during the year ended June 30, 1928. It includes 770 publications, classified as follows: Meteorology, 12; soils and fertilizers, 39; field crops, 93; horticulture, 83; forestry, 8; plant diseases, 47; entomology and zoology, 53; foods and human nutrition, 18; animal production, 89; dairying, 42; diseases of livestock, 23; agricultural engineering, 28; economics and sociology, 117; and reports, periodicals, regulatory, and miscellaneous publications, 118.

METEOROLOGY

Meteorological observations at the Massachusetts Agricultural Experiment Station. J. E. Ostrander et al. Mass. Sta. Met. Buls. 462–474, 4 p. each. 1927–1928.

SOILS—FERTILIZERS

SOILS

Woodford County Soils. R. S. Smith, E. E. DeTurk, F. C. Bauer, and L. H. Smith. Ill. Sta. Soil Rpt. 36, 57 p., illus. 1927.

Lee County Soils. R. S. Smith, O. I. Ellis E. E. DeTurk, F. C. Bauer, and L. H. Smith. Ill. Sta. Soil Rpt. 37, 65 p., illus. 1927.

Ogle County Soils. R. S. Smith, O. I. Ellis, E. E. DeTurk, F. C. Bauer, and L. H. Smith. Ill. Sta. Soil Rpt. 38, 60 p., illus 1927.

Logan County Soils. R. S. Smith, E. E. DeTurk, F. C. Bauer, and L. H. Smith. Ill. Sta. Soil Survey Rpt. 39, 56 p., illus. 1927.

Soil Survey of Iowa.—Greene County Soils. W. H. Stevenson, P. E. Brown, et al. Iowa Sta. Soil Survey Rpt. 44, 72 p., illus. 1927.

Soil Survey of Iowa.—Des Moines County Soils. W. H. Stevenson, P. E. Brown, et al. Iowa Sta. Soil Survey Rpt. 45, 72 p., illus. 1927.

Soil Survey of Iowa.—Benton County Soils. W. H. Stevenson, P. E. Brown, et al. Iowa Sta. Soil Survey Rpt. 46, 72 p., illus. 1927.

Soil Survey of Iowa.—Grundy County Soils. W. H. Stevenson, P. E. Brown, et al. Iowa Sta. Soil Survey Rpt. 47, 59 p., illus. 1927.

Soil Survey of Iowa.—Floyd County Soils. W. H. Stevenson, P. E. Brown, et al. Iowa Sta. Soil Survey Rpt. 48, 71 p., illus. 1927.

Soil Survey of Iowa.—North County Soils W. H. Stevenson, P. E. Brown, et al Iowa Sta. Soil Survey Rpt. 49, 75 p., illus. 1927.

The Soils of Bowie, Denton, Freestone and Red River Counties. G. S. Fraps. Tex. Sta. Bul. 375, 48 p., illus. 1928.

Zeolite Formation and Base-Exchange Reactions in Soils. P. S. Burgess and W. T. McGeorge. Ariz. Sta. Tech. Bul. 15, p. [359]–399, illus. 1927.

Vitamin-Like Substances in Plant Nutrition. J. F. Breazeale. Ariz. Sta. Tech. Bul. 16, p. 400–417, illus. 1927.

The Action of Aluminum, Ferrous and Ferric Iron, and Manganese in Base-Exchange Reactions. O. C. Magistad. Ariz. Sta. Tech. Bul. 18, p. 445–463. 1928.

Alkali Soil Studies and Methods of Reclamation. P. S. Burgess. Ariz. Sta. Bul. 123, p. 156–181, illus. 1928.

Hungarian Alkali Soils and Methods of Their Reclamation. A. A. J. De 'Sigmond. Calif. Sta. Spec. Pub., 156 p., illus. 1927.

The Effect of Green Manures and Crop Residues on Soil Reaction. W. G. Sackett, A. Kezer, I. W. Ferguson, and J. C. Ward. Colo. Sta. Bul. 324, 31 p. 1928.

The Maintenance of Crop Production on Semi-Arid Soil. F. J. Sievers and H. F. Holtz. Wash. Col. Sta. Pop. Bul. 138, 29 p., illus. 1927.

The General Soil Flora. H. J. Conn. The Bacterial Flora of Four Soils Compared by the Direct Microscopic Method. L. M. Thatcher and H. J. Conn. N. Y. State Sta. Tech. Bul. 129, 27 p. 1927.

The Numbers of Microorganisms in Carrington Loam as Influenced by Different Soil Treatments. L. W. Erdman. Iowa Sta. Res. Bul. 109, p. 229–259, illus. 1928.

Soil Sterilization for Seedbeds and Greenhouses. W. G. Sackett. Colo. Sta. Bul. 321, 24 p., illus. 1927.

Studies on Nitrification and Its Relation to Crop Production on Carrington Loam Under Different Treatment. L. W. Erdman and H. Humfeld. Iowa Sta. Res. Bul. 110, p. 261–291, illus. 1928.

The Recovery of Soil Nitrogen Under Various Conditions as Measured by Lysimeters of Different Depths. C. A. Mooers, W. H. MacIntire, and J. B. Young. Tenn. Sta. Bul. 138, 30 p., illus. 1927.

Relation of the Potash Removed by Crops to the Active, Total, Acid-Soluble, and Acid-Insoluble Potash of the Soil. G. S. Fraps. Tex. Sta. Bul. 355, 33 p., illus. 1927.

Crop Yields from Illinois Soil Experiment Fields in 1926. F. C. Bauer. Ill. Sta. Bul. 296, p. 19–40, illus. 1927.

Lessons from the Morrow Plots. E. E. DeTurk, F. C. Bauer, and L. H. Smith. Ill. Sta. Bul. 300, p. 106–140, illus. 1927.

Crop Yields from Illinois Soil Experiment Fields in 1927. F. C. Bauer. Ill. Sta. Bul. 305, p. 343–369. 1928.

FERTILIZERS

Artificial Manure Production on the Farm. W. A. Albrecht. Mo. Sta. Bul. 258, 20 p., illus. 1927.

Artificial Manure from Straw. R. C. Collison and H. J. Conn. N. Y. State Sta. Circ. 95, 3 p. 1928.

The Degree of Response of Different Crops to Various Phosphorus Carriers. B. L. Hartwell and S. C. Damon. R. I. Sta. Bul. 209, 19 p. 1927.

The Agricultural Value of Specially Prepared Blast-Furnace Slag, Preliminary Report. J. W. White. Pa. Sta. Bul. 220, 19 p., illus. 1928.

Economic Values of Different Forms and Amounts of Agricultural Lime. J. W. White and F. J. Holben. Pa. Sta. Bul. 211, 23 p., illus. 1927.
The Effect of Sulphur on Soils and on Crop Yields. R. R. McKibbin. Md. Sta. Bul. 296, p. 65–114, illus. 1928.
The Stimulation of Plant Response on the Raw Peat Soils of the Florida Everglades Through the Use of Copper Sulphate and Other Chemicals. (A preliminary report.) R. V. Allison, C. C. Bryan, and J. H. Hunter. Fla. Sta. Bul. 190, p. 33–80, illus. 1927.
A Preliminary Report on the Value of Hairy Vetch and Crimson Clover for Green Manure. R. P. Bledsoe. Ga. Sta. Bul. 146, p. 187–208. 1927.
A Nitrogen Factory on Every Farm. O. H. Sears. Ill. Sta. Circ. 326, 12 p., illus. 1928.
New Fertilizers on the Market for 1928: Suggestions for Their Use. C. A. Mooers. Tenn. Sta. Circ. 18, 2 p. 1928.
Fertilizers for West Tennessee. C. A. Mooers. Tenn Sta. Circ. 20, 4 p., illus. 1928.
Fertilizer Ratios for Prince George County. A. G. McCall. Md. Sta. Bul. 294, p. 35–51, illus. 1928.

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Impermeable Seed of Alfalfa. A. M. Lute. Colo. Sta. Bul. 326, 36 p., illus. 1928.
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Report of the Agricultural Experiment Station of the University of California, from July 1, 1926, to June 30, 1927. E. D. Merrill et al. 110 p. 1927.

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Report of Moses Fell Annex Farm, Bedford, Indiana, June, 1928. H. J. Reed and H. G. Hall. Ind. Sta. Circ. 152, 18 p., illus. 1928.

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Annual Report [Michigan Station] for the Fiscal Year Ending June 30, 1926. R. S. Shaw et al. 23 p.

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Report of the Northwest Experiment Station, Crookston, [Minn.], 1926. C. G. Selvig. 63 p., illus.

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Commercial Feeding Stuffs from September 1, 1926, to August 31, 1927. B. Youngblood, F. D. Fuller, and S. D. Pearce. Tex. Sta. Bul. 370, 132 p. 1927.

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STATISTICS, 1928

By J. I. Schulte

The following tables give detailed data regarding (1) personnel, publications, and mailing lists of the experiment stations (2) revenues and additions to equipment; (3) expenditures from the Hatch, Adams, and Purnell funds; and (4) total disbursements from the United States Treasury under the Hatch, Adams, and Purnell Acts from their passage to the end of the fiscal year, June 30, 1928.

Table 2.—*Personnel, publications, and mailing lists of experiment stations, 1928*

Station	Date of original organization	Date of organization under Hatch Act	Persons on staff	Teachers on staff	Persons on staff who assist in extension work	Publications during fiscal year		Names on mailing list
						Number	*Pages*	
Alabama	Feb. —, 1883	Feb. 24, 1888	33	16	0	5	207	2,100
Alaska			6			1	40	3,000
Arizona		—, 1889	34	26	0	8	206	4,500
Arkansas		—, 1887	39	28		9	552	6,000
California	—, 1875	Mar. —, 1888	168	85	80	52	2,294	4,122
Colorado		Feb. 29, 1888	63	34	6	15	535	800
Connecticut (State)	Oct. 1, 1875	May 18, 1887	39		0	10	487	14,405
Connecticut (Storrs)		do	22	10	1	7	340	11,000
Delaware		Feb. 21, 1888	23	8	4	5	220	6,000
Florida		—, 1888	59	1	12	39	652	10,000
Georgia	Feb. 18, 1888	July 1, 1889	21	1	0	33	74	7,000
Guam			5			1	19	
Hawaii			7			2	68	1,500
Idaho		Feb. 26, 1892	50	26	6	26	837	19,344
Illinois		Mar. 21, 1888	127	81	37	302	2,169	21,248
Indiana	—, 1885	Jan. —, 1888	106	21		61	1,415	36,169
Iowa		Feb. 17, 1888	103	49		36	1,214	18,266
Kansas		Feb. 8, 1888	102	76		14	414	13,500
Kentucky	Sept. —, 1885	Apr. —, 1888	64	23	5	7	398	12,600
Louisiana	Apr. —, 1886		38	9	2	3	206	5,641
Maine	Mar. —, 1885	Oct. 1, 1887	28	2		12	331	17,436
Maryland	—, 1888	Apr. —, 1888	43	23	6	9	196	34,000
Massachusetts	—, 1882	Mar. 2, 1888	68	14		30	484	15,000
Michigan		Feb. 26, 1888	93	64	4	35	1,180	35,000
Minnesota	Mar. 7, 1885	—, 1888	139	123	64	21	948	36,000
Mississippi		Jan. 27, 1888	46	14		96	421	18,000
Missouri		Jan. —, 1888	83	62		76	1,480	4,800
Montana		July 1, 1893	49	19	8	14	575	6,000
Nebraska	Dec. 16, 1884	June 13, 1887	48	17		10	265	8,476
Nevada		Dec. —, 1887	15	1	0	7	175	7,000
New Hampshire	—, 1886	Aug. 4, 1887	39	19	17	12	277	7,500
New Jersey (State)	Mar. 10, 1880		[1] 78	52	50	248	1,237	21,000
New Jersey (college)		Apr. 26, 1888	39					
New Mexico		Dec. 14, 1889	26	13	7	124	443	10,000
New York (Cornell)	—, 1879	Apr. —, 1888	81	40	12	21	1,160	7,996
New York (State)	Mar. —, 1882		57			36	815	40,000
North Carolina	Mar. 12, 1877	Mar. 7, 1887	48	9	0	5	152	3,200
North Dakota		Mar. —, 1890	55	20	4	15	796	8,000
Ohio	Apr. 25, 1882	Apr. 2, 1888	111	18	2	74	840	74,500
Oklahoma		Dec. 25, 1890	44	26		28	296	4,500
Oregon		July —, 1888	67	39	37	18	368	1,655
Pennsylvania		June 30, 1887	101	74	37	18	781	48,135
Porto Rico			8			2	39	3,000
Rhode Island		July 30, 1888	18	3		11	139	4,000
South Carolina		Jan. —, 1888	38	11	8	9	466	6,000
South Dakota		Mar. 13, 1887	32	32	3	10	344	7,000
Tennessee	June 8, 1882	Aug. 4, 1887	32	2		17	145	13,680
Texas		Apr. 3, 1889	89	0		40	838	66,467
Utah		—, 1890	39	25	5	10	298	9,075
Vermont	Nov. 24, 1886	Feb. 26, 1888	25	8	1	10	326	4,000
Virginia	—, 1888	—, 1891	40	12	2	10	254	12,000
Virgin Islands			4			1	17	500
Washington		—, 1891	58	23		14	604	14,978
West Virginia		June 11, 1888	44	23	6	119	552	16,785
Wisconsin	—, 1883	—, 1887	111	88	65	23	1,019	59,396
Wyoming		Mar. 1, 1891	33	13	1	6	161	8,000
Total			3,013	1,383	492	1,827	30,769	830,274

[1] Including 25 also on college station staff, not included in total.

TABLE 3.—*Revenues and additions to*

Station	Revenues						
	Federal			State	Balances from previous year [1]	Fees	Sales
	Hatch fund	Adams fund	Purnell fund				
Alabama	$15,000	$15,000	$40,000	$70,181.84	$6,734.24	----------	$11,037.47
Alaska [2]	----------	----------	----------	----------	----------	----------	----------
Arizona	15,000	15,000	40,000	114,348.46	2,402.53	----------	12,574.80
Arkansas	15,000	15,000	40,000	72,248.14	----------	----------	20,384.18
California	15,000	15,000	40,000	649,067.45	3,519.56	$11,213.42	97,213.46
Colorado	15,000	15,000	40,000	109,399.51	27,251.84	----------	37,480.69
Connecticut (State)	7,500	7,500	20,000	179,520.79	201.46	20,000.00	----------
Connecticut (Storrs)	7,500	7,500	20,000	37,000.00	5,567.98	----------	----------
Delaware	15,000	15,000	40,000	18,500.00	2,836.89	----------	16,443.63
Florida	15,000	15,000	40,000	319,105.00	3,337.56	----------	16,121.87
Georgia	15,000	15,000	40,000	50,000.00	5,663.56	----------	7,489.31
Guam [2]	----------	----------	----------	----------	----------	----------	----------
Hawaii [2]	----------	----------	----------	----------	----------	----------	----------
Idaho	15,000	15,000	40,000	52,162.05	1,126.23	----------	4,033.65
Illinois	15,000	15,000	40,000	427,173.05	26,101.75	----------	71,042.37
Indiana	15,000	15,000	40,000	238,507.40	105,395.09	164,195.99	86,260.28
Iowa	15,000	15,000	40,000	235,000.00	8,326.06	----------	40,657.89
Kansas	15,000	15,000	40,000	105,690.00	20,206.61	47,408.06	24,780.97
Kentucky	15,000	15,000	40,000	136,892.07	4,734.47	124,786.64	56,202.40
Louisiana	15,000	15,000	40,000	65,000.00	1,785.71	32,921.17	16,384.20
Maine	15,000	15,000	40,000	35,000.00	1,402.14	11,083.90	18,943.47
Maryland	15,000	15,000	40,000	65,448.04	5,832.85	----------	25,179.10
Massachusetts	15,000	15,000	40,000	146,781.61	----------	59,421.88	23,428.70
Michigan	15,000	15,000	40,000	310,679.06	----------	----------	35,367.00
Minnesota	15,000	15,000	40,000	318,969.93	----------	----------	112,912.42
Mississippi	15,000	15,000	40,000	151,775.00	11,187.83	----------	20,995.05
Missouri	15,000	15,000	40,000	36,584.51	29,701.29	32,538.75	79,874.29
Montana	15,000	15,000	40,000	117,589.45	----------	----------	36,772.17
Nebraska	15,000	15,000	40,000	192,139.47	----------	----------	59,497.82
Nevada	15,000	15,000	40,000	2,259.70	1,061.29	----------	5,798.78
New Hampshire	15,000	15,000	40,000	5,500.00	----------	----------	2,728.24
New Jersey (State)	----------	----------	----------	269,277.06	----------	47,328.01	40,400.21
New Jersey (College)	15,000	15,000	40,000	----------	----------	----------	----------
New Mexico	15,000	15,000	40,000	7,500.00	18,211.71	----------	11,084.62
New York (State)	1,500	1,500	4,000	292,555.00	5,463.68	----------	15,587.95
New York (Cornell)	13,500	13,500	36,000	256,130.51	----------	----------	39,798.87
North Carolina	15,000	15,000	40,000	123,153.88	2,448.05	----------	58,212.05
North Dakota	15,000	15,000	40,000	303,195.00	26,143.54	----------	90,755.81
Ohio [3]	15,000	15,000	40,000	1,058,372.65	113,686.99	----------	56,700.19
Oklahoma	15,000	15,000	40,000	40,000.00	3,044.48	----------	21,046.31
Oregon	15,000	15,000	40,000	133,000.00	46,995.92	----------	63,906.63
Pennsylvania	15,000	15,000	40,000	97,553.62	194.71	----------	1,792.84
Porto Rico [2]	----------	----------	----------	----------	----------	----------	----------
Rhode Island [4]	15,000	15,000	40,000	----------	717.54	----------	5,650.30
South Carolina	15,000	15,000	40,000	82,176.70	----------	----------	59,445.05
South Dakota	15,000	15,000	40,000	33,791.75	14,416.80	----------	12,821.10
Tennessee	15,000	15,000	40,000	40,723.42	----------	----------	16,650.85
Texas	15,000	15,000	40,000	356,482.73	54,716.48	----------	124,634.55
Utah	15,000	15,000	40,000	61,472.25	----------	----------	27,873.44
Vermont	15,000	15,000	40,000	----------	----------	18,451.10	1,675.80
Virginia	15,000	15,000	40,000	87,088.33	11,715.53	----------	12,321.51
Virgin Islands [2]	----------	----------	----------	----------	----------	----------	----------
Washington	15,000	15,000	40,000	107,737.04	17,213.43	----------	74,214.85
West Virginia	15,000	15,000	40,000	93,500.00	2,167.65	----------	56,182.41
Wisconsin	15,000	15,000	40,000	285,379.25	----------	----------	80,012.75
Wyoming	15,000	15,000	40,000	63,067.79	1,504.57	----------	392.48
Total	720,000	720,000	1,920,000	8,054,679.51	593,018.02	569,348.92	1,810,764.78

[1] Not including balances from Federal funds.
[2] Supported by direct appropriations to the United States Department of Agriculture.
[3] State appropriation for 18 months.
[4] Including balance of $2,944 on Adams fund.

equipment, experiment stations, 1928

Revenues		Additions to equipment						
Miscellaneous	Total	Buildings	Library	Apparatus	Farm implements	Livestock	Miscellaneous	Total
-----	$157,953.55	$10,501.99	$677.97	$5,195.69	$4,589.09	$100.11	$1,393.02	$22,457.87
$76,240.00	76,240.00	-----	-----	-----	-----	-----	-----	-----
-----	199,325.79	1,723.99	-----	597.20	7,725.13	911.91	3,462.15	14,420.38
-----	162,632.32	7,386.74	1,641.00	6,449.94	2,480.27	782.97	1,370.76	20,111.68
24.708.84	855,722.73	165,396.58	16,461.38	-----		-----	-----	181,857.96
-----	244,132.04	6,102.00	840.00	3,697.00	2,568.00	19,314.00	26,700.00	59,221.00
10,917.77	245,640.02	2,951.78	1,283.58	2,677.26	1,455.79	110.00	3,534.79	12,013.20
18,072.63	95,640.61	899.47	589.52	1,420.95	518.72	-----	1,625.61	5,054.27
-----	107,780.52	1,557.66	1,010.43	2,042.96	1,468.14	-----	-----	6,079.19
-----	408,564.43	37,298.38	4,463.69	8,775.45	12,566.19	884.75	9,485.62	73,474.08
-----	133,152.87	65,000.00	500.00	1,500.00	2,500.00	1,200.00	-----	70,700.00
25,000.00	25,000.00	-----	-----	-----	-----	-----	-----	-----
54,940.00	54,940.00	-----	-----	-----	-----	-----	-----	-----
-----	127,321.93	1,669.68	124.91	708.73	2,828.95	3,561.97	-----	8,894.24
-----	594,317.17	13,925.08	-----	-----	20,476.93	-----	-----	34,402.01
56,606.36	720,965.12	31,340.48	849.87	8,415.80	10,428.90	2,939.58	3,678.32	57,652.95
-----	353,983.95	75,079.33	-----	-----	1,245.30	-----	447.33	76,771.96
-----	268,085.64	9,815.99	32.49	3,046.21	14,084.49	16,456.86	3,614.01	47,050.05
5,000.00	397,615.58	10,551.42	1,129.54	1,672.72	2,341.22	1,752.24	580.70	18,027.84
27,833.43	213,924.51	6,305.52	357.83	945.42	2,636.88	3,316.78	3,357.81	16,920.24
-----	136,429.51	1,370.58	935.27	1,225.32	2,354.75	32.33	-----	5,918.25
26,787.06	193,247.05	-----	394.01	1,713.72	3,270.00	1,126.86	8,113.23	14,617.82
-----	299,632.19	2,093.30	435.35	5,246.00	6,371.97	56.91	1,732.08	15,935.61
538.77	416,584.83	1,450.00	359.00	5,986.00	3,129.00	1,093.00	2,232.00	14,249.00
19,868.73	521,751.08	57,556.33	1,533.60	11,618.86	12,057.27	8,061.53	-----	90,827.59
5,400.00	259,357.88	6,165.00	107.52	1,774.76	2,361.87	1,676.00	596.29	12,681.44
-----	248,698.84	3,853.28	621.17	5,761.90	3,888.92	-----	-----	14,125.27
37.74	224,399.36	-----	588.00	2,615.00	3,500.00	1,000.00	1,200.00	8,903.00
-----	321,637.29	39,558.47	382.42	3,769.88	4,640.55	18,798.73	919.52	68,069.57
-----	79,119.77	113.55	235.00	172.65	262.11	70.00	149.00	1,002.31
25,978.88	104,207.12	2,937.01	685.30	2,021.35	1,617.65	331.00	971.00	8,563.31
147.40	357,152.68	15,000.00	1,984.05	5,770.37	1,000.00	572.05	1,631.59	25,958.06
-----	70,000.00	-----	-----	-----	-----	-----	-----	-----
-----	106,796.33	6,220.05	95.52	712.28	2,190.24	3,555.69	4,100.00	16,873.78
-----	320,606.63	-----	2,318.24	2,377.85	2,026.69	4.00	-----	6,726.78
-----	358,929.38	1,531.30	2,554.59	3,511.55	3,262.71	378.35	4,445.76	15,684.26
3,308.11	257,122.09	8,318.00	276.57	2,064.40	440.13	2,277.05	32.51	13,408.66
39,472.86	529,567.21	30,705.06	677.38	1,976.85	6,030.83	10,688.15	12,016.07	62,094.34
4,412.99	1,303,172.82	40,493.95	582.44	5,154.16	33,862.86	13,385.59	1,989.04	95,468.04
-----	134,090.79	1,177.06	763.90	3,522.72	3,098.40	2,242.77	1,478.88	12,283.73
7,368.26	321,270.81	4,022.22	208.56	1,664.29	4,589.70	3,104.55	-----	13,589.32
16,924.02	186,465.19	697.05	93.09	5,388.21	362.08	492.73	1,965.27	8,998.43
56,460.00	56,460.00	-----	-----	-----	-----	-----	-----	-----
-----	76,367.84	4,587.00	406.00	421.00	1,100.00	38.00	1,995.00	8,547.00
-----	211,621.75	30,998.68	3,746.81	2,552.49	44.01	1,706.54	3,525.64	42,574.17
4,728.14	135,757.79	-----	351.50	2,290.55	1,538.90	-----	1,660.00	5,840.95
-----	127,374.27	8,121.26	657.88	2,244.71	1,742.99	1,159.50	900.28	14,826.62
64,293.76	670,127.52	30,838.76	13,954.58	11,516.36	6,021.78	6,982.25	12,040.78	81,354.51
-----	159,345.69	850.00	337.40	1,354.70	3,369.65	710.00	500.00	7,121.75
440.00	90,566.90	3,037.43	440.15	1,212.84	1,218.69	48.00	-----	5,957.11
530.00	181,655.37	9,882.00	1,358.74	2,410.62	2,182.99	400.00	1,013.53	17,247.88
25,000.00	25,000.00	-----	-----	-----	-----	-----	-----	-----
-----	269,165.32	2,692.26	1,731.67	419.51	1,049.21	1,117.17	749.35	7,759.17
-----	221,850.06	20,000.00	598.00	1,432.00	2,110.00	5,732.00	990.00	30,862.00
51,586.08	486,978.08	1,780.00	1,407.71	15,799.09	4,253.97	2,840.16	2,115.31	28,196.24
-----	134,964.84	15,919.41	900.00	2,334.78	2,038.27	5,483.09	560.00	27,235.55
652,601.83	15,040,413.06	799,475.10	71,683.63	165,182.10	216,902.19	146,495.17	128,872.25	1,528,610.44

TABLE 4.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$15,000	$9,350.66	$2,030.48	$561.54	$369.91	$41.43	$14.50	$180.62
Arizona	15,000	14,649.76	11.05		.45			67.69
Arkansas	15,000	6,575.00	2,933.17	2,551.26	90.70	182.36	110.18	252.25
California	15,000	15,000.00						
Colorado	15,000	14,803.01	35.18		5.77			14.35
Connecticut (State)	7,500	7,500.00						
Connecticut (Storrs)	7,500	7,500.00						
Delaware	15,000	9,630.80	1,019.85	1,084.78	684.45	17.39	267.49	75.07
Florida	15,000	15,000.00						
Georgia	15,000	9,105.00	1,356.68	319.25	638.76	234.51	600.43	18.75
Idaho	15,000	10,612.40	3,028.04	10.73	21.00		5.97	521.49
Illinois	15,000	15,000.00						
Indiana	15,000	15,000.00						
Iowa	15,000	8,391.85	602.82	1,299.59	9.60	19.44	17.19	93.25
Kansas	15,000	9,700.00	4,533.35		50.80	36.68	27.50	44.20
Kentucky	15,000	14,835.13		84.26				
Louisiana	15,000	4,691.64	7,386.36	200.00	205.44	26.39	173.53	
Maine	15,000	8,508.00	2,409.95		50.15	41.18	774.80	
Maryland	15,000	14,730.00			60.77			110.76
Massachusetts	15,000	14,867.02						
Michigan	15,000	15,000.00						
Minnesota	15,000	15,000.00						
Mississippi	15,000	10,421.96	2,489.12		262.31	84.12	202.77	
Missouri	15,000	8,798.92	1,305.80	53.93	127.33	48.31	90.76	128.58
Montana	15,000	7,125.00	3,461.11	1,398.44	580.52	15.20	23.18	65.22
Nebraska	15,000	15,000.00						
Nevada	15,000	9,197.65	2,308.86	757.46	794.38	7.90	35.00	27.48
New Hampshire	15,000	9,742.46	786.05	856.31	764.50	312.21	700.00	79.85
New Jersey	15,000	10,950.00	1,105.70	3.00	435.66	3.15	122.46	265.42
New Mexico	15,000	8,004.80	3,145.00	1,601.31	128.98	110.03	332.02	180.78
New York (Cornell)	13,500	8,586.75	3,139.24		84.80	27.13	5.28	374.12
New York (State)	1,500	1,368.54						
North Carolina	15,000	12,213.00	205.98	379.18	213.77	35.00	1.14	38.16
North Dakota	15,000	15,000.00						
Ohio	15,000	5,760.00	3,715.75	290.24	402.60		612.96	1,140.83
Oklahoma	15,000	6,730.04	2,879.91	953.15	218.60	20.95	45.60	784.78
Oregon	15,000	10,387.55	2,001.60		63.44	53.60	20.93	99.50
Pennsylvania	15,000	12,300.00	991.53	1,480.19		24.81		
Rhode Island	15,000	5,483.08	4,017.84	702.03	263.30	191.94	212.51	11.24
South Carolina	15,000	8,433.30	2,412.36	971.64	162.86	88.04	17.82	96.41
South Dakota	15,000	8,211.60	3,356.16	1,296.99	97.35	1.52		176.95
Tennessee	15,000	9,130.00	2,331.18	490.72	423.76	74.04	1,200.41	47.63
Texas	15,000	14,547.50	135.00		120.00			
Utah	15,000	11,129.18	990.13		15.20	57.99		42.79
Vermont	15,000	8,529.77	1,198.38	1,134.45	732.46	69.93	1,294.46	59.88
Virginia	15,000	9,216.60	3,413.61	282.04	331.72	41.61	158.40	118.85
Washington	15,000	11,049.01	1,627.62	1,372.96	36.41			9.25
West Virginia	15,000	6,899.94	3,038.55					230.35
Wisconsin	15,000	11,600.00	720.00	377.84	25.48			846.15
Wyoming	15,000	9,445.15	5,544.00					
Total	720,000	520,712.07	81,667.41	20,513.29	8,473.23	1,866.86	7,067.29	6,202.65

the act of March 2, 1887 (Hatch Act), for the year ended June 30, 1928

Classified expenditures										
Seeds plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and land
$196.77	$371.71	$603.00	$399.66	$167.72	$68.59	$41.55		$148.01		$453.85
				43.10		31.50		177.14	$0.32	18.99
361.23	89.25	489.12	64.61	129.67	16.31	514.42	$27.44	558.35		54.68
.45		33.47	72.35		8.00	1.67		25.75		
107.56	96.35		529.90	189.60	857.78			348.43	21.55	69.00
636.18	64.19		293.14	405.03	122.20	19.80	250.00	936.08		
269.87		23.00	5.00	9.30	27.00			449.80		16.40
1,484.42	104.01	2,832.25		23.96	14.90	31.73		74.99		
97.30				282.74	11.89	11.46		192.35		11.73
								80.61		
43.69	199.50	106.75		1,705.45			250.00			11.25
192.71		1,972.40	502.25	17.27	6.52	245.41		279.36		
1.00			38.05	2.33				57.09		
								132.98		
634.71		112.89	24.51	331.98	.27			431.26		4.10
542.69		2,656.24	503.72	21.71	12.00	209.45	109.80	334.93		55.83
69.47		513.57	87.90	189.60	155.22		172.00	1,142.47	1.10	
217.74		658.84	14.35	40.60	419.07			488.97		31.70
119.12	68.93		362.18	2.15	63.88	460.22		655.89	1.68	24.57
174.84	7.00	360.00	76.70	118.30	273.20	208.05		825.64	37.72	33.16
309.30	362.73	34.85	1.26	386.74	59.91		1.10	149.81		191.38
421.83	153.30	13.92	30.88	238.73	56.53	357.70		9.79		
						88.14		43.32		
101.21				78.70	292.69			1,441.17		
306.67	156.00	1,689.94		151.93	4.73	379.35				389.00
625.02		567.85	37.60	629.73	190.54	237.03	360.00	716.20	3.00	
983.55	3.25	628.14	16.18	166.00			129.65	446.61		
155.63	45.23			2.61						
723.65	473.96	354.64	495.98	537.70	98.93	100.00		586.16	10.00	737.04
690.38	400.00	600.00	328.72	323.16	236.96			238.35		
392.15		648.78	7.50	172.70	117.78	420.57				99.95
170.15	36.44		509.74	133.32	58.45	14.59		214.53	.60	164.44
							168.00			29.50
243.33		1,519.50	5.50	35.83	64.00			896.55		
254.21	60.33		370.36	533.11	196.41	36.48		248.53	5.00	276.24
407.19	13.43	1.20	274.81	123.14	153.20	104.15		256.57	7.70	95.78
61.44	10.12			84.00	5.50			743.69		
1,323.25	409.19	25.25		590.11		1,342.23		1,133.73		7.40
168.61		11.00		422.41	406.05	387.22		35.24		
								10.85		
12,487.32	3,124.92	16,456.60	5,052.85	8,290.43	3,998.51	5,242.72	1,467.99	14,511.20	88.67	2,775.99

TABLE 5.—*Expenditures from United States appropriations received under*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies	Seeds, plants, and sundry supplies
Alabama	$15,000	$11,050.00	$378.61	$101.01	$111.88	$139.47	$1,104.86	$142.96
Arizona	15,000	11,400.00	1,755.02	14.49	55.96		178.83	234.28
Arkansas	15,000	9,137.50	2,481.99	8.16	136.54		894.99	303.16
California	15,000	15,000.00						
Colorado	15,000	15,000.00						
Connecticut (State)	7,500	7,500.00						
Connecticut (Storrs)	7,500	7,500.00						
Delaware	15,000	11,254.00	745.30	3.20	18.64	.84	1,210.04	156.63
Florida	15,000	15,000.00						
Georgia	15,000	10,705.00	772.79	8.20	174.82	425.42	227.95	161.44
Idaho	15,000	10,762.38	2,003.11	32.17		7.40	1,176.13	309.89
Illinois	15,000	10,509.83	4,490.17					
Indiana	15,000	12,890.01	413.75	9.82	25.81		488.38	130.27
Iowa	15,000	8,971.86	2,899.38	49.59		34.50	1,101.77	348.00
Kansas	15,000	10,300.00	3,279.41		4.92		256.42	37.58
Kentucky	15,000	14,667.93	156.09		7.65		119.93	24.58
Louisiana	15,000	10,925.01	1,565.66	31.27	3.45	509.46	798.76	171.88
Maine	15,000	15,000.00						
Maryland	15,000	13,805.00	44.00	10.63			208.75	74.16
Massachusetts	15,000	14,500.00						
Michigan	15,000	15,000.00						
Minnesota	15,000	15,000.00						
Mississippi	15,000	9,689.92	3,413.40	2.00	36.72	110.30	71.01	294.19
Missouri	15,000	5,303.41	3,845.11	57.08	242.22	101.98	903.07	421.53
Montana	15,000	11,289.63	1,668.46	16.97	19.74	1.25	197.55	292.37
Nebraska	15,000	15,000.00						
Nevada	15,000	11,049.07	2,530.72	25.85	8.54		60.19	33.31
New Hampshire	15,000	12,174.00	1,204.07	67.01	23.91		356.19	90.63
New Jersey	15,000	11,750.00	259.11	12.76	4.99	851.05	1,088.80	108.54
New Mexico	15,000	9,828.96	2,157.38	61.42	155.98	642.00	871.08	187.50
New York (Cornell)	13,500	12,732.20	210.48	.64	7.73		316.86	30.00
New York (State)	1,500	1,500.00						
North Carolina	15,000	11,920.00	293.66	59.31	200.27	38.60	508.47	86.49
North Dakota	15,000	15,000.00						
Ohio	15,000	9,794.99	3,698.19	11.47		229.92	126.29	11.87
Oklahoma	15,000	11,172.50	1,208.17	19.20	6.81		657.80	359.77
Oregon	15,000	12,850.00	850.63	48.15	46.08	51.27	486.52	207.69
Pennsylvania	15,000	14,083.81	429.09		.91		62.76	83.23
Rhode Island [1]	15,000	10,280.17	1,595.02	11.74	52.83	244.76	151.18	412.50
South Carolina	15,000	11,038.37	1,499.76	161.33	30.94	382.30	204.66	246.50
South Dakota	15,000	7,541.58	4,348.03	47.41	45.38	61.05	425.35	269.89
Tennessee	15,000	13,340.00	360.25	14.75	80.59	152.93	189.34	38.31
Texas	15,000	13,208.34	766.71	.01	56.23	37.26	678.68	133.22
Utah	15,000	10,300.08	2,398.25	24.38	46.00		980.06	170.27
Vermont	15,000	10,404.17	2,350.75	8.95	46.17	19.67	368.83	404.73
Virginia	15,000	14,124.92	42.60	.59			117.68	1.25
Washington	15,000	11,692.38	1,833.58	6.61			670.07	29.40
West Virginia	15,000	11,287.46	515.73	4.98		2.80	307.18	403.73
Wisconsin	15,000	10,750.00	3,322.77				464.38	
Wyoming	15,000	14,162.00	838.00					
Total	720,000	579,146.48	62,625.20	931.15	1,651.71	4,044.23	18,030.81	6,411.75

[1] Including balance from previous year, $2,944.

the act of March 16, 1906 (Adams Act), for the year ended June 30, 1928

Classified expenditures									
Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Livestock	Traveling expenses	Contingent expenses	Buildings and land
$10.05		$2.43	$260.40	$13.44	$1,626.54		$57.20		$1.15
19.80		67.57	152.70		14.69		727.41	$379.25	
93.38	$274.13	267.62	109.47	38.57	814.85	$9.45	420.17		10.02
		34.48	5.70	563.50	797.44		209.89	.34	
29.38	1,560.39	6.15	143.41		10.80	462.52	269.01		42.72
	123.65		7.44		80.58		495.75	1.50	
	627.46		23.58		241.62	123.32	25.98		
23.28	863.10		2.38	54.25	628.76		23.13		
	743.30				29.28	326.40	11.00	4.65	7.04
					23.82				
	90.52	225.60	8.15	2.75	356.72		135.15		175.62
			192.11	2.80	555.46				107.09
					500.00				
143.56		5.00	809.10		223.64	135.00	59.46	1.60	5.10
	2,624.29		394.30	184.21	464.29	331.82	100.08	1.00	25.61
		17.95	376.37	37.75	442.55	61.00	555.91		22.50
	842.19	6.30			9.58	120.40	313.85		
	131.06		282.88	92.71	63.30		140.90	1.50	371.84
			32.75	274.40	123.45		48.13	46.41	399.61
169.16	23.50	7.40	377.32	185.00			50.67		282.63
		6.89	25.20		170.00				
4.50	133.98		10.34		800.06		944.32		
	58.51		220.04	30.00	61.25	704.35			53.12
10.00	1,131.94		109.25		290.43		34.13		
51.00	1.14	4.80	148.26		197.12		18.24		39.10
14.00		80.25	25.45		220.50				
537.50	1,035.70	24.25	15.73	2.40	141.79	30.00	144.32		320.11
			154.02		1,113.16		18.96		150.00
82.99	67.01	297.00	26.51	230.00	578.51		481.09		498.20
		28.93	169.13	60.98	523.25		3.00		38.54
	20.00	8.85	25.30	10.00	49.90	5.50			
			188.87	1.80	201.57		575.72	113.00	
	674.10	21.40	138.27	19.12	349.12	48.00	141.18		5.54
	303.90		3.00		330.62		75.44		
		40.50	8.40	65.30	99.60		554.16		
72.87	395.14		206.34	7.00	1,318.81	45.90	432.06		
	186.20		14.65		254.50	7.50			
1,261.47	11,911.21	1,153.37	4,666.82	1,875.98	13,707.56	2,411.16	7,066.31	549.25	2,555.54

TABLE 6.—*Expenditures from United States appropriations received under the*

Station	Amount of appropriation	Classified expenditures						
		Salaries	Labor	Publications	Postage and stationery	Freight and express	Heat, light, and water	Chemical supplies
Alabama	$40,000	$21,556.67	$6,493.32	$18.75	$263.35	$577.76	$183.60	$1,800.71
Arizona	40,000	25,441.54	1,878.86	117.60	76.98	70.05	74.79	452.04
Arkansas	40,000	29,501.11	1,899.08	2,774.51	626.07	85.21	32.54	467.02
California	40,000	35,178.15	4,821.85					
Colorado	40,000	31,150.74	911.68	319.15	245.83	47.50		527.09
Connecticut (State)	20,000	10,659.66	3,143.47		73.07		15.98	475.34
Connecticut (Storrs)	20,000	10,461.65	7,026.17		243.29			
Delaware	40,000	26,228.01	1,259.37	504.50	148.52	114.31	463.84	1,675.73
Florida	40,000	25,905.63	2,644.01	699.02	1,340.12	10.73	71.62	1,478.01
Georgia	40,000	24,780.00	5,270.33	535.00	289.75	280.41	970.71	442.86
Idaho	40,000	25,007.48	2,472.12	2,226.62	116.08	236.51		199.69
Illinois	40,000	24,500.46	5,311.15	1,158.55	628.37	116.18		503.82
Indiana	40,000	26,250.00	6,491.96	670.54	224.82	20.61	2.40	29.18
Iowa	40,000	21,443.56	6,612.98	1,502.45	525.12	32.08	22.51	361.57
Kansas	40,000	22,499.93	12,307.52		17.70	129.74	130.98	568.69
Kentucky	40,000	33,874.07	1,819.89	225.73	169.79	25.74		415.61
Louisiana	40,000	25,473.45	6,895.88		145.04	486.70	338.88	481.58
Maine	40,000	32,356.18	33.00		430.54	101.59	5.46	412.41
Maryland	40,000	30,847.99	3,295.15		171.73	12.95		348.42
Massachusetts	40,000	30,072.50	1,316.46	1,557.03	251.26	10.61		577.57
Michigan	40,000	28,778.97	5,138.52	521.87	653.70	20.48		834.92
Minnesota	40,000	32,777.08	1,950.00	912.60	55.21	20.26		109.49
Mississippi	40,000	25,322.47	6,693.97	427.32	188.79	578.49	226.45	93.34
Missouri	40,000	17,763.09	8,065.84	1,508.50	461.81	274.28	335.24	1,681.41
Montana	40,000	25,846.26	4,034.38	44.40	279.31	55.39		626.10
Nebraska	40,000	26,996.67	2,981.75	187.89	96.24	124.69	19.10	283.86
Nevada	40,000	21,135.00	6,482.87		670.58	138.90	153.83	159.77
New Hampshire	40,000	25,951.36	3,787.65	584.87	107.94	52.49		474.02
New Jersey	40,000	29,792.50	1,996.81	54.50	61.72	14.06	543.12	1,411.95
New Mexico	40,000	17,518.06	5,611.57	887.03	216.58	480.64	163.95	65.77
New York (Cornell)	36,000	31,245.82	763.44	81.40	456.99	40.01		480.37
New York (State)	4,000	2,166.64	1,383.36					
North Carolina	40,000	23,011.47	2,724.02	413.28	204.57	181.84	64.77	581.03
North Dakota	40,000	37,354.54	23.52		43.72			
Ohio	40,000	27,581.25	4,710.95	252.00	234.65	4.99	291.36	812.38
Oklahoma	40,000	26,028.05	4,491.37	100.00	421.94	28.53	22.49	1,138.41
Oregon	40,000	22,362.92	7,143.89	1,003.76	220.46	116.37	35.54	689.86
Pennsylvania	40,000	25,123.20	2,835.36	1,749.18	337.99	337.29	139.92	533.07
Rhode Island	40,000	24,019.66	5,078.90	241.90	277.28	194.22	456.71	192.76
South Carolina	40,000	24,848.28	5,603.13	941.84	513.26	59.74		306.45
South Dakota	40,000	22,918.98	4,854.83	2,956.25	483.04	49.34	14.93	785.93
Tennessee	40,000	31,636.65	1,381.15		53.89	201.28	185.14	1,001.55
Texas	40,000	19,351.67	8,950.36		703.33	230.30		2,638.99
Utah	40,000	26,860.30	4,002.49	538.56	551.84	276.46	8.30	495.01
Vermont	40,000	22,791.75	5,749.11	1,636.99	916.04	62.38	508.15	325.39
Virginia	40,000	23,539.08	5,437.43	315.70	551.42	37.38	9.99	495.23
Washington	40,000	25,179.18	5,501.39	2,695.05	216.11	19.35	6.30	46.31
West Virginia	40,000	27,584.56	4,083.76		65.31	174.46	40.00	299.01
Wisconsin	40,000	22,734.79	12,691.58	44.53	113.26	1.50		553.74
Wyoming	40,000	27,814.33	4,487.20	853.70	45.19	104.41		127.51
Total	1,920,000	1,259,223.36	220,544.85	31,262.57	15,189.60	6,238.21	5,538.60	28,460.97

act of February 24, 1925 (Purnell Act), for the year ended June 30, 1928

Classified expenditures—Continued										
Seeds, plants, and sundry supplies	Fertilizers	Feeding stuffs	Library	Tools, implements, and machinery	Furniture and fixtures	Scientific apparatus	Live-stock	Traveling expenses	Contingent expenses	Buildings and land
$657.53	$232.94	$294.13	$255.88	$1,248.60	$456.03	$3,201.54	$29.00	$2,629.64	--------	$100.55
2,285.63	81.82	--------	--------	642.60	365.00	3,545.32	--------	4,967.77	--------	--------
73.13	--------	143.88	372.57	226.70	167.39	1,064.96	--------	2,515.06	--------	50.77
--------	--------	--------	--------	--------	--------	--------	--------	--------	--------	--------
61.57	--------	8.80	47.10	7.65	516.54	436.48	--------	3,404.66	$340.00	1,975.21
27.79	--------	--------	--------	1,619.02	712.60	1,345.47	--------	1,750.60	25.92	151.08
10.70	--------	--------	16.08	--------	--------	--------	--------	2,242.11	--------	--------
753.86	276.24	1,647.96	246.02	363.20	1,132.04	1,245.52	--------	2,085.74	27.35	1,827.79
328.61	269.52	154.09	--------	279.34	1,190.82	2,171.59	--------	3,224.31	23.55	209.03
514.95	214.15	3,495.86	125.25	545.06	465.82	957.46	197.57	888.27	--------	26.55
221.52	--------	559.97	86.22	211.26	166.17	266.61	3,043.25	5,169.91	16.59	--------
112.66	--------	95.26	14.24	1,279.99	1,576.65	986.78	103.91	3,551.98	--------	60.00
225.25	--------	--------	12.50	126.76	604.92	689.22	--------	4,645.84	6.00	--------
1,132.57	21.00	2,429.97	21.43	300.44	874.48	509.37	560.37	2,919.94	18.00	712.16
166.95	--------	134.98	--------	345.55	--------	1,134.39	2,059.52	484.73	--------	19.32
105.12	--------	999.85	149.81	--------	16.10	170.59	--------	2,027.70	--------	--------
983.25	443.24	491.02	14.00	1,339.35	--------	5.54	899.37	1,833.57	--------	169.13
249.16	36.15	25.50	.87	395.67	1,131.89	919.97	--------	2,899.54	907.66	94.41
484.53	--------	--------	5.00	90.22	998.93	508.62	561.54	2,627.53	--------	47.39
146.35	--------	256.91	32.49	234.89	591.89	1,641.29	56.91	3,206.19	7.35	40.30
851.58	--------	60.64	76.92	242.38	636.86	4.50	27.00	2,136.40	15.26	--------
178.93	--------	117.58	--------	45.94	1,051.72	820.29	236.23	1,554.50	--------	170.17
415.28	146.80	793.17	66.34	1,515.55	796.34	1,387.87	92.20	1,079.12	--------	176.50
1,611.55	--------	3,361.54	20.49	1,082.75	604.36	1,188.35	369.90	1,137.05	22.25	511.59
570.97	284.61	515.20	376.20	590.27	93.05	1,587.90	49.22	5,044.74	2.00	--------
145.39	--------	3,018.21	6.00	295.07	134.51	2,047.98	432.92	1,997.65	2.40	1,229.67
538.65	78.15	2,891.65	7.75	779.72	2,051.67	212.68	250.00	4,098.40	--------	350.38
492.44	250.42	131.50	24.47	620.62	685.93	912.63	331.00	3,264.54	14.07	2,314.05
168.44	18.00	492.66	107.35	677.61	712.62	1,377.67	6.25	2,270.27	10.46	284.01
2,513.32	72.85	2,085.47	7.67	942.74	342.98	73.87	3,289.52	4,351.31	24.80	1,351.87
241.88	59.10	619.76	10.84	182.59	412.69	461.46	31.50	811.55	95.00	5.60
--------	--------	--------	--------	--------	--------	450.00	--------	--------	--------	--------
689.51	113.00	3,961.60	--------	341.09	53.45	852.65	2,277.05	3,012.01	--------	1,518.66
76.53	--------	258.50	5.01	--------	--------	--------	--------	2,238.18	--------	--------
576.31	4.35	4,514.43	--------	135.23	--------	808.78	--------	73.32	--------	--------
694.84	--------	1,845.96	--------	819.71	1,260.85	658.75	1,074.50	730.23	4.25	680.12
980.36	--------	--------	16.34	2,245.52	355.30	396.85	66.00	3,928.68	438.15	--------
209.78	14.75	195.80	--------	1,198.45	2.00	2,018.25	144.00	5,041.97	20.00	98.99
471.21	272.80	2,011.65	124.72	672.76	937.45	177.88	8.00	811.06	400.00	3,651.04
418.04	--------	693.67	--------	204.74	626.10	783.02	--------	5,001.73	--------	--------
162.46	--------	1,329.46	47.00	446.95	1,663.18	1,101.62	56.25	3,074.30	--------	55.48
354.14	27.35	--------	250.63	730.84	338.93	911.57	--------	1,269.51	.50	1,656.87
339.72	--------	573.25	83.00	20.98	886.09	3,587.17	87.50	1,629.89	--------	917.75
916.52	27.00	499.72	15.00	340.96	600.05	77.23	7.50	4,116.26	--------	666.80
164.06	--------	283.41	41.39	485.48	2,143.49	246.08	--------	1,873.92	107.50	2,664.86
93.38	--------	--------	108.74	279.99	583.53	429.07	--------	7,237.06	--------	882.00
1,088.84	--------	--------	46.70	163.80	1,449.56	508.59	--------	3,078.82	--------	--------
1,002.89	89.50	3,198.24	20.00	119.78	48.56	1,019.17	--------	2,234.49	--------	20.27
455.58	34.80	345.33	--------	387.20	226.27	377.94	133.98	1,801.40	--------	98.10
187.74	--------	1,465.40	4.50	737.04	3.25	197.18	377.23	3,569.21	9.94	16.17
25,151.47	3,068.54	46,001.98	2,866.52	25,562.06	29,668.06	45,477.72	16,859.19	131,542.66	2,539.00	24,804.64

TABLE 7.—*Disbursements from the United States Treasury to the States and Territories for agricultural experiment stations under the acts of Congress approved March 2, 1887, March 16, 1906, and February 24, 1925*

State or Territory	Hatch Act		Adams Act		Purnell Act	
	1888–1927	1928	1906–1927	1928	1926–27	1928
Alabama	$598,956.42	$15,000	$296,619.89	$15,000	$50,000.00	$40,000
Arizona	564,803.10	15,000	299,955.61	15,000	50,000.00	40,000
Arkansas	598,139.12	15,000	299,900.00	15,000	50,000.00	40,000
California	600,000.00	15,000	299,926.84	15,000	50,000.00	40,000
Colorado	599,718.82	15,000	298,638.93	15,000	50,000.00	40,000
Connecticut	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Dakota Territory	56,250.00					
Delaware	598,382.87	15,000	295,475.12	15,000	49,295.10	40,000
Florida	599,966.04	15,000	299,996.06	15,000	46,523.74	40,000
Georgia	595,593.43	15,000	287,092.87	15,000	50,000.00	40,000
Idaho	524,324.13	15,000	295,842.22	15,000	50,000.00	40,000
Illinois	599,564.95	15,000	299,851.62	15,000	50,000.00	40,000
Indiana	599,901.19	15,000	300,000.00	15,000	50,000.00	40,000
Iowa	600,000.00	15,000	300,000.00	15,000	47,965.17	40,000
Kansas	599,995.00	15,000	300,000.00	15,000	50,000.00	40,000
Kentucky	599,996.57	15,000	300,000.00	15,000	50,000.00	40,000
Louisiana	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Maine	599,999.62	15,000	300,000.00	15,000	50,000.00	40,000
Maryland	599,967.40	15,000	299,236.48	15,000	50,000.00	40,000
Massachusetts	599,617.70	15,000	300,000.00	15,000	50,000.00	40,000
Michigan	599,676.10	15,000	296,341.20	15,000	50,000.00	40,000
Minnesota	599,917.78	15,000	299,345.00	15,000	50,000.00	40,000
Mississippi	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Missouri	595,097.24	15,000	299,999.90	15,000	50,000.00	40,000
Montana	510,000.00	15,000	297,417.04	15,000	50,000.00	40,000
Nebraska	599,932.16	15,000	300,000.00	15,000	50,000.00	40,000
Nevada	599,214.32	15,000	298,180.28	15,000	50,000.00	40,000
New Hampshire	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
New Jersey	599,949.97	15,000	299,392.06	15,000	50,000.00	40,000
New Mexico	564,509.05	15,000	300,000.00	15,000	50,000.00	40,000
New York	599,757.18	15,000	299,463.01	15,000	50,000.00	40,000
North Carolina	600,000.00	15,000	285,000.00	15,000	50,000.00	40,000
North Dakota	541,502.26	15,000	299,638.85	15,000	50,000.00	40,000
Ohio	600,000.00	15,000	298,514.02	15,000	50,000.00	40,000
Oklahoma	524,002.16	15,000	279,535.19	15,000	50,000.00	40,000
Oregon	585,156.64	15,000	295,000.00	15,000	50,000.00	40,000
Pennsylvania	599,967.43	15,000	299,995.41	15,000	50,000.00	40,000
Rhode Island	600,000.00	15,000	297,464.20	12,056	50,000.00	40,000
South Carolina	599,542.15	15,000	298,460.12	15,000	50,000.00	40,000
South Dakota	543,250.00	15,000	295,000.00	15,000	50,000.00	40,000
Tennessee	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Texas	600,000.00	15,000	297,592.26	15,000	50,000.00	40,000
Utah	465,000.00	15,000	299,821.94	15,000	50,000.00	40,000
Vermont	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Virginia	597,824.12	15,000	299,949.01	15,000	50,000.00	40,000
Washington	537,102.65	15,000	296,080.11	15,000	50,000.00	40,000
West Virginia	599,968.71	15,000	297,859.12	15,000	50,000.00	40,000
Wisconsin	600,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Wyoming	585,000.00	15,000	300,000.00	15,000	50,000.00	40,000
Total	28,181,546.28	720,000	14,302,584.36	717,056	2,393,784.01	1,920,000

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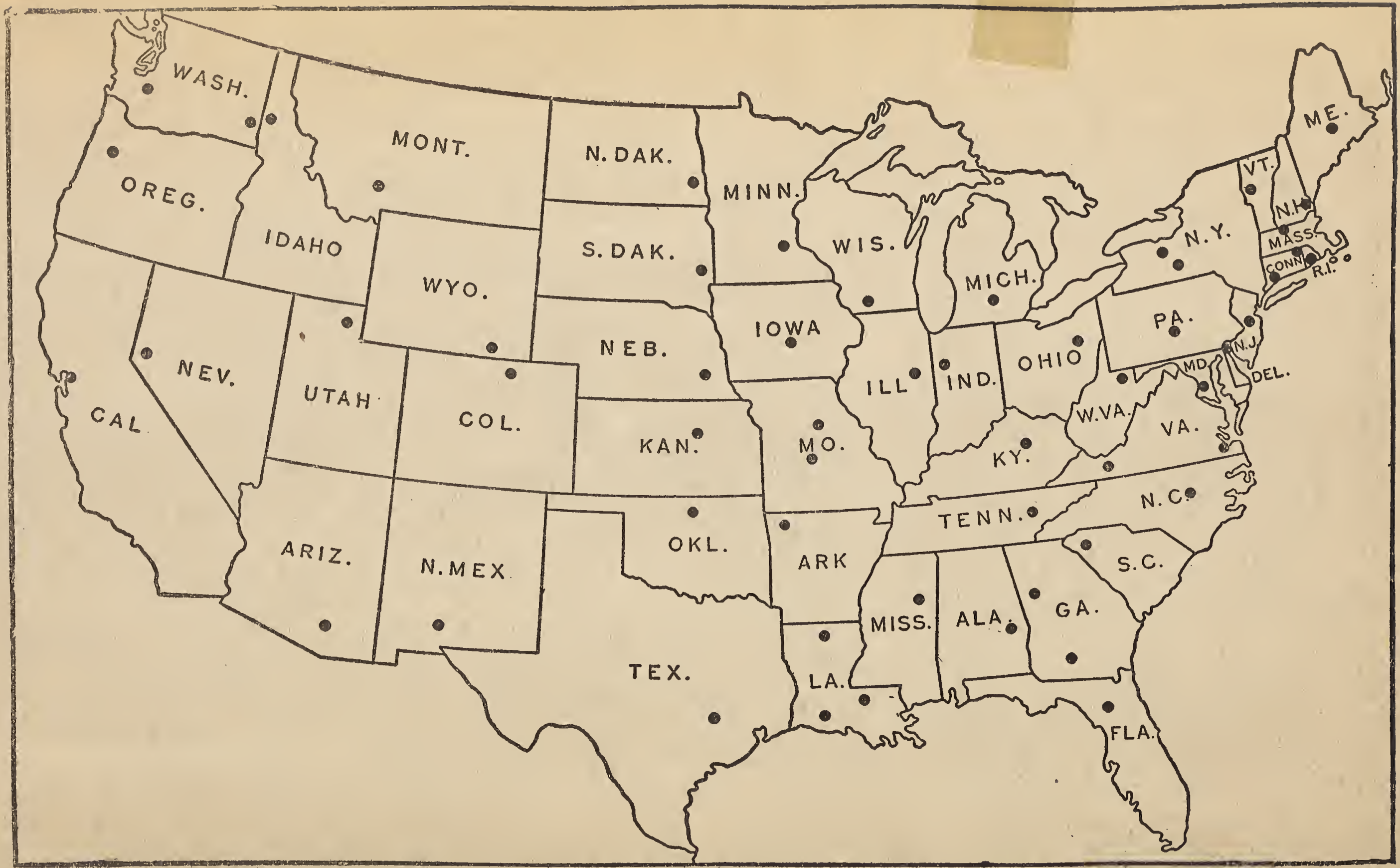

THE AGRICULTURAL EXPERIMENT STATIONS OF THE UNITED STATES

U. S. GOVERNMENT PRINTING OFFICE: 1929